

**Comments of**

**COALITION FOR SAFE BUILDING MATERIALS**

**(California Pipe Trades Council, California Professional Firefighters,  
Consumer Federation of California, Planning and Conservation League,  
Center for Environmental Health, Sierra Club of California and  
Communities for a Better Environment)**

on the

**DRAFT ENVIRONMENTAL IMPACT REPORT  
FOR**

**ADOPTION OF REGULATIONS PERMITTING STATEWIDE RESIDENTIAL USE  
OF CHLORINATED POLYVINYL CHLORIDE (CPVC) PLASTIC PLUMBING  
PIPE WITHOUT FIRST MAKING A FINDING OF POTENTIAL PREMATURE  
METALLIC PIPE FAILURE DUE TO LOCAL WATER OR SOIL CONDITIONS  
*STATE CLEARINGHOUSE NO. 2006012044***

**VOLUME IV**

***APPENDICES TO THE COMMENTS OF  
ADAMS BROADWELL JOSEPH & CARDOZO***

September 14, 2006



**DECLARATION OF THOMAS A. ENSLOW  
IN SUPPORT OF THE COMMENTS OF  
THE COALITION FOR SAFE BUILDING MATERIALS**

Date: September 13, 2006

1. I am an attorney at law employed by the firm of Adams Broadwell Joseph & Cardozo.
2. On March 1, 2006, I submitted a public record request for all documents related to chlorinated polyvinyl chloride ("CPVC") plastic pipe in the possession or control of the Department of Housing and Community Development ("HCD").
3. On March 30, 2006, HCD provided me copies of records in response to my March 1, 2006 request.
4. On April 14, 2006, I spoke with Robin Gilb, the HCD staff counsel who was then preparing the draft environmental impact report on the statewide approval of CPVC, State Clearinghouse No. 2006012044 ("DEIR"). She informed me that she had additional correspondence with representatives of the CPVC industry that were not provided in response to our document request.
5. I spoke with HCD staff counsel, Lisa Kan Yu, by telephone on April 17, 2006 and again on May 3, 2006. She confirmed that HCD had withheld documents related to CPVC under the attorney client privilege and deliberative process privileges. She further stated that correspondence and documents sent to or from representatives of the CPVC industry had been withheld under the "catch-all" exemption of Government Code section 6255.
6. On May 8, 2006, I submitted a new public record request asking HCD for all documents related to CPVC plastic pipe, including those that I believed had been improperly withheld under the deliberative process and catch-all exemptions.
7. On June 5, 2006, HCD provided me access to records in response to my public record requests, including numerous records that had been previously withheld. On June 15, 2006, HCD supplemented their response with several additional records that had been inadvertently withheld.
8. On August 1, 2006, I submitted a public record request for "all documents referenced or relied upon to support conclusions in the [DEIR]."
9. On August 4, 2006, HCD provided me access to records in response to my August 1, 2006 request.

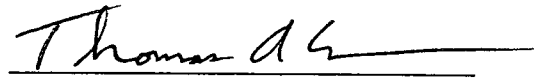
10. On August 9, 2006, HCD staff attorney Robin Gilb emailed me a list of nine additional documents that were responsive to my August 1, 2006 request.
11. I personally reviewed each and every document that HCD made available in response to my March 1, 2006, May 8, 2006 and August 1, 2006 record requests.
12. The documents provided in response to our August 1, 2006 request for all documents relied upon to support conclusions in the DEIR contained no substantive evaluation of the issues evaluated in the DEIR by state technical experts or outside consultants, other than responses for raw data regarding future housing projections, CPVC market estimates, and average primer and cement usage.
13. The DEIR provides a list of persons "consulted" in the preparation of the DEIR ("the consultants").
  - a. The documents provided in response to my March 1, 2006, May 8, 2006 and August 1, 2006 record requests contained no substantive written reports, analyses or evaluation by the "consultants" on any of the impacts evaluated in the DEIR.
  - b. The documents provided in response to my March 1, 2006, May 8, 2006 and August 1, 2006 record requests contained no evidence or indication that any of the "consultants" were provided a complete description of the project evaluated in the DEIR or provided copies of expert comments, technical reports and other substantial evidence that had been submitted to HCD during its 2005 CPVC proceedings.
14. The documents provided in response to my March 1, 2006, May 8, 2006 and August 1, 2006 record requests contained no evidence that HCD obtained or independently evaluated the studies and data that served as the basis for NSF/ANSI 14 and NSF/ANSI 61 standards or that it reviewed NSF testing protocols or results regarding CPVC potable water piping. The only documents that HCD obtained from NSF were: (1) its NSF/ANSI 14 and NSF/ANSI 61 standards; (2) its general certification policies for plastic pipe and drinking water system components; and (3) its general standards development and maintenance policies.
15. The documents provided in response to my March 1, 2006, May 8, 2006 and August 1, 2006 record requests contained no evidence or indication that the preparers of the DEIR consulted with agency or outside technical experts regarding the determination of appropriate thresholds of significance.
16. On April 25, 2006, I submitted a public record request to the California Air Resources Board ("CARB") for all documents relating to CPVC or CARB's consideration of the authorization of CPVC in building standards proposed by HCD.



17. On May 16, 2006, CARB provided documents in response to my April 25, 2006 request. Among those documents were emails dated May 1, 2006, between Judy Yee, a section manager at the Stationary Sources Division of CARB, and Robin Gilb, Staff attorney at HCD. In this email, Ms. Gilb asked CARB's opinion as to whether the DEIR should apply local air district's operational or construction thresholds of significance. Ms. Yee suggested using both methods.
18. The DEIR concludes that neither operational or construction thresholds of significance are appropriate.
19. The documents provided to me by HCD in response to the March 1, 2006, May 8, 2006 and August 1, 2006 record requests did not include the May 1, 2006 email between Ms. Yee and Ms. Gilb.
20. On August 30, 2006, I submitted a new public record request to HCD asking for all documents related to CPVC except for those provided in response to my earlier requests. In this letter I expressly alerted HCD to their failure to provide the May 1, 2006 email between Ms. Yee and Ms. Gilb.
21. On September 11, 2006, I received a faxed letter from HCD stating that they would not provide me a response to my August 30, 2006 request for another two weeks. This delay ensured that I would be unable to review their response until after the September 12, 2006 deadline for submitting comments on the DEIR had passed.

I declare under penalty of perjury of the State of California that the foregoing is true and correct.

Executed September 13, 2006, at Sacramento, California.

  
Thomas A. Enslow



# Environmental Impacts of Polyvinyl Chloride Building Materials

by Joe Thornton, Ph.D.



**A Healthy Building Network Report**

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by Joe Thornton, Ph.D.

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**A Healthy Building Network Report**

This report was prepared by the author and does not represent the opinions of The University of Oregon or any of its affiliates

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The United States

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p. 53 © Basel Action Network. PVC coated wire waste sorted and burned by villagers in Guiyu, China. Cancer causing polycyclic aromatic hydrocarbons and dioxins will result from burning wires made from PVC and brominated flame retardants.

p. 77 © Bryce Iankard/Greenpeace 1996. Cows graze outside PVC manufacturing facility in Giesmar, Louisiana. Dioxin emissions to the environment move up the food chain. Fatty foods such as meat and dairy products are the primary source of dioxin exposure to most humans.

p. 97 © Stone/Greenpeace 200. Lake Charles, Louisiana area children suffer health impacts due to pollution from PVC manufacturing facilities.

## Acknowledgements

The Healthy Building acknowledges the following people and organizations for their important contributions to this report.

Dr. Joe Thornton's willingness to accept this assignment on short notice and under a short deadline is testament to his ongoing commitment to the related goals of sound science and environmental justice.

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Barbra Batshalom, Founder & Executive Director, the Green Roundtable ([www.greenroundtable.org](http://www.greenroundtable.org))

Mark Rossi, Health Care Without Harm ([www.noharm.com](http://www.noharm.com))

Ted Schettler, MD, MPH of the Science Environmental Health Network ([www.sehn.org](http://www.sehn.org))

Jan Stensland, Principal, Inside Matters ([www.insidematters.com](http://www.insidematters.com))

Gail Vittori, Co-Director, Center for Maximum Potential Building Systems ([www.cmpbs.org](http://www.cmpbs.org))

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Bill Walsh  
National Coordinator  
Healthy Building Network  
November, 2002

## About the Author

Joe Thornton, Ph.D., is Assistant Professor in the Center for Ecology and Evolutionary Biology at the University of Oregon. His research focuses on the health and policy implications of global chemical pollution and on the molecular evolution of animal endocrine systems. He holds Ph.D., M.A., and M.Phil. degrees in Biological Sciences from Columbia University and a B.A. from Yale University.

Dr. Thornton is the author of *Pandora's Poison: Chlorine, Health, and a New Environmental Strategy* (MIT Press 2000), which the British scientific journal *Nature* has called "a landmark book which should be read by anyone wanting to understand the environmental and health dangers of chlorine chemistry." From the late 1980s to the mid-1990s, Thornton was research analyst and then research coordinator for Greenpeace's U.S. and international toxics campaigns. There, he authored seminal reports and articles on organochlorines, dioxin, breast cancer, waste incineration, risk assessment, and the precautionary principle. In 1995, Dr. Thornton joined Columbia University's Earth Institute, where he wrote *Pandora's Poison* and expanded his research into the basic science of the biological systems that can be damaged by toxic chemicals. He also co-authored the article and American Public Health Association resolution that launched the campaign to eliminate polyvinyl chloride (PVC) products from medical uses due to their central role in dioxin formation in medical waste incinerators. Dr. Thornton has spoken before the U.S. Congress, the EPA Science Advisory Board, the American Association for the Advancement of Science, the American Public Health Association, the International Joint Commission, and a variety of other organizations and audiences. His work has been published in numerous scientific journals, including *Proceedings of the National Academy of Sciences*, *Annual Review of Genomics and Human Genetics*, *Public Health Reports*, *Bioessays*, *Systematic Biology*, and *International Journal of Occupational and Environmental Health*.



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## Summary of Findings

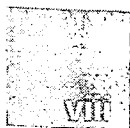
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In the last 40 years, polyvinyl chloride plastic (PVC) has become a major building material. Global vinyl production now totals over 30 million tons per year, the majority of which is directed to building applications, furnishings, and electronics.

The manufacture, use, and disposal of PVC poses substantial and unique environmental and human health hazards. Across the world, governments, companies, and scientific organizations have recognized the hazards of PVC. In virtually all European nations, certain uses of PVC have been eliminated for environmental reasons, and several countries have ambitious programs to reduce PVC use overall. Scores of communities have PVC avoidance policies, and dozens of green buildings have been built with little or no PVC. Firms in a variety of industries have announced measures to reduce PVC consumption and are using or producing alternative materials in a variety of product sectors, including building materials. This paper discusses the hazards of the PVC lifecycle that have led to this large scale movement away from PVC products.

The major hazards of the PVC lifecycle discussed in this report are summarized below.

**PVC production is the largest use of chlorine gas in the world.** PVC consumes about 40 percent of total chlorine production, or approximately 16 million tons of chlorine per year worldwide. PVC is the largest production-volume organochlorine, a large class of chemicals that have come under scientific and regulatory scrutiny in the last decade because of their global distribution and the unusually severe hazards they tend to pose. PVC (vinyl) is the only major building material that is an organochlorine; alternative materials, including most other plastics, do not contain chlorine and do not pose the hazards discussed in this report.



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**Hazardous by-products are formed throughout the PVC lifecycle.** At numerous points in the vinyl lifecycle, very large quantities of hazardous organochlorine by-products are formed accidentally and released into the environment.

**Production:** Formation of hazardous organochlorine by-products begins with the production of chlorine gas. Extremely large quantities—on the order of one million tons per year—of chlorine-rich hazardous wastes are generated in the synthesis of ethylene dichloride and vinyl chloride monomer (EDC and VCM, the feedstocks for PVC).

**Combustion:** Still more by-products are created and released to the environment during the incineration of hazardous wastes from EDC and VCM production, the incineration of vinyl products in the waste stream, the recycling of vinyl-containing metal products by combustion, and the accidental burning of PVC in fires in buildings, warehouses, or landfills.

**By-products of PVC production are highly persistent, bioaccumulative, and toxic.** The chemical mixtures produced in the synthesis of EDC and VCM include such extremely hazardous and long-lived pollutants as the chlorinated dioxins (polychlorinated dibenzo-p-dioxins), chlorinated furans (polychlorinated dibenzofurans), PCBs (polychlorinated biphenyls), hexachlorobenzene (HCB), and octachlorostyrene (OCS). In addition, a very large portion of these mixtures consists of chemicals that have not yet been identified or tested. Many of the by-products of the vinyl lifecycle are of great concern, because of their persistent bioaccumulative toxicity:

**Persistence** means that a substance resists natural degradation, builds up over time in the environment, and can be distributed globally on currents of wind and water. Many of the by-products of the PVC lifecycle are now ubiquitous global pollutants, which can be found not only in industrialized regions but in the planet's most remote ecosystems. Absolutely every person on earth is now exposed to these substances.



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**Bioaccumulation** means that a substance is fat-soluble and therefore builds up in the tissues of living things. Most bioaccumulative substances, including many formed during the PVC lifecycle, magnify as they move up the food chain, reaching concentrations in species high on the food chain that are millions of times greater than their levels in the ambient environment. These substances also cross the placenta easily and concentrate in the breast milk of human and other mammals.

**Toxicity.** The feedstocks, additives, and by-products produced and released during the lifecycle of PVC have been shown to cause a range of health hazards, in some cases at extremely low doses, including:

- Cancer
- Disruption of the endocrine system
- Reproductive impairment
- Impaired child development and birth defects
- Neurotoxicity (damage to the brain or its function), and
- Immune system suppression.

When its entire lifecycle is considered, vinyl appears to be associated with more dioxin formation than any other single product.

**Dioxins.** Among the most important by-products of the PVC lifecycle are dioxin (2,3,7,8-tetrachlorodibenzo-p-dioxin) and a large group of structurally and toxicologically related compounds, collectively called dioxins or dioxin-like compounds. Dioxins are never manufactured intentionally but are formed accidentally whenever chlorine gas is used or chlorine-based organic chemicals are burned or processed under reactive conditions.

**Dioxins are formed during numerous stages of the vinyl lifecycle.**

Formation of dioxins has been documented in production of chlorine, synthesis of the feedstocks EDC and VCM, burning of vinyl products in accidental fires, and incineration of vinyl products and the hazardous wastes from PVC production.

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**Vinyl is a major dioxin source.** Vinyl is the predominant chlorine donor and therefore a major and preventable cause of dioxin formation in most of the leading dioxin sources that have been identified. When its entire lifecycle is considered, vinyl appears to be associated with more dioxin formation than any other single product.

**Dioxins are global pollutants.** Dioxins are now found in the tissues of whales in the deep oceans, polar bears in the high Arctic, and virtually every human being on earth. Human infants receive particularly high doses (orders of magnitude greater than those of the average adult), because dioxins cross the placenta easily and concentrate in breast milk.

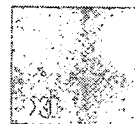
**There is no known safe dose of dioxin.** Dioxin causes damage to development, reproduction, and the immune and endocrine systems at infinitesimally low doses (in the low parts per trillion). Toxicological studies have not been able to establish a "threshold" dose below which dioxin does not cause biological impacts.

**Dioxin is a potent carcinogen.** Dioxin is the most potent synthetic carcinogen ever tested in laboratory animals and is a known human carcinogen.

**Dioxin poses health risks to the general public that are already too high.** The dioxin "body burden" of the general human population of the United States is already in the range at which adverse health impacts occur in laboratory animals. The dioxin exposure of the average American already poses a calculated cancer risk of one in 1,000 to one in 100—thousands of times greater than the usual standard for an "acceptable risk."

**Phthalate plasticizers.** In its pure form, PVC is rigid and brittle. To make flexible vinyl products, such as roofing materials, floor tiles and wall coverings, plasticizers must be added to PVC in large quantities – up to 60 percent of the final product by weight. The dominant group of plasticizers used in vinyl are a class of compounds called phthalates, which pose considerable health and environmental hazards. Vinyl is the only major building

The dioxin exposure of the average American already poses a calculated cancer risk of one in 1,000 to one in 100—thousands of times greater than the usual standard for an "acceptable risk."



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product in which phthalates are used extensively, and it accounts for about 90 percent of total phthalate consumption. Over 5 million tons of phthalates are used in vinyl every year.

**Phthalates have become global pollutants.** Phthalates are moderately bioaccumulative and moderately persistent under some conditions. They can now be found in the water of the deep oceans, air in remote regions, and the tissues and fluids of the general human population. Infants and toddlers are subject to exposures several times higher than those of the average adult.

**Massive quantities of phthalates are released into the environment each year.** Millions of pounds of phthalates are released annually into the environment during the formulation and molding of vinyl products. Phthalates are also released when vinyl is disposed of in landfills or incinerators or when PVC products burn accidentally. More than 80 million tons of phthalates are estimated to be contained in the stock of PVC products now in use in buildings and other applications.

**Phthalates leach out of vinyl products.** Phthalates are not chemically bonded to the plastic but are merely mixed with the polymer during formulation. They therefore leach out of the plastic over time into air, water, or other substances with which vinyl comes in contact.

**Phthalates damage reproduction and development.** Phthalates have been found to damage the reproductive system, causing infertility, testicular damage, reduced sperm count, suppressed ovulation, and abnormal development and function of the testes and male reproductive tract in laboratory animals. They are known carcinogens in laboratory animals.

**DEHP exposure is already too high.** An expert committee of the National Toxicology Program recently reviewed the hazards of diethylhexyl phthalate (DEHP, the most common vinyl plasticizer) and expressed "concern that exposure [of infants and toddlers in the general U.S. population] may adversely affect male reproductive tract develop-



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ment" and "concern that ambient oral DEHP exposures to pregnant or lactating women may adversely affect the development of their offspring." The average American's dose of the plasticizer DEHP is now approximately equal to EPA's reference dose – the maximum "acceptable" exposure based on studies of health impacts in laboratory animals.

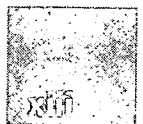
**Lead and other heavy metal stabilizers.** Because PVC catalyzes its own decomposition, metal stabilizers are added to vinyl for construction and other extended-life applications. Common PVC additives that are particularly hazardous are lead, cadmium, and organotins, with global consumption of each by vinyl estimated in the thousands of tons per year.

**Metals do not degrade in the environment.** All three of the major PVC stabilizers resist environmental breakdown and have become global pollutants.

**Metal stabilizers are highly toxic.** Lead is an exquisitely potent developmental toxicant, damaging brain development and reducing the cognitive ability and IQ of children in infinitesimal doses. Cadmium is a potent neurotoxin and carcinogen, and organotins can suppress immunity and disrupt the endocrine system.

**Metal stabilizers are released through out the vinyl product lifecycle.** Metal stabilizers are released from vinyl products when they are formulated, used, and disposed. Releases of lead stabilizers from interior vinyl building products have been documented. Metals cannot be destroyed by incineration but are released entirely into the environment, via air emissions or ash residues. Trash incinerators are a dominant source of lead and cadmium pollution, and PVC contributes a significant amount of these metals—an estimated 45,000 tons of lead each year—to incinerators.

Accidental fires in buildings and landfills are also potentially important sources of lead, cadmium, and organotins. In a fire, metals in PVC will be released to the environment; an astounding 3.2 million tons of lead are present in the current stock of PVC in use. Potential lead releases from this stored PVC must be viewed as a major potential health hazard.





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**Flexible PVC harms indoor air quality.** Flexible vinyl products appear to contribute to the health hazards of poor indoor air by releasing phthalates and facilitating the growth of hazardous molds.

**PVC products release phthalates into the building environment.**

Phthalate levels in indoor air in buildings with PVC are typically many times higher than in outdoor air. Phthalate accumulation in suspended and sedimented indoor dusts are particularly high, with concentrations in dust as high as 1,000 parts per million.

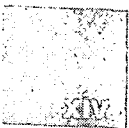
**PVC phthalate exposure may be linked to asthma.** In laboratory animals, metabolites of phthalates used in vinyl cause asthma-like symptoms through a well-described inflammatory mechanism. Three separate epidemiological studies have found that human exposure to PVC in building interiors causes significantly elevated risks of asthma and other pulmonary conditions, including bronchial obstruction, wheezing, pneumonia, prolonged cough, and irritation of the nasal passages and eyes.

**PVC products can release heavy metals into the building**

**environment.** Metal stabilizers, particularly lead, cadmium, and organotin, can be released from vinyl products. Significant quantities of lead have been found to be released from vinyl window blinds into air and from PVC pipes into water. Toxicological effects of these substances include neurological, development, and reproductive damage.

**Vinyl wall covering encourages toxic mold growth.** Because vinyl wall coverings form a barrier impermeable to moisture, they encourage the growth of molds on wall surfaces beneath the vinyl, particularly in buildings where air conditioning or heating systems produce significant temperature and humidity differentials between rooms and wall cavities. Some molds that grow beneath vinyl produce toxic substances that are released into indoor air and are suspected causes of severe human health problems. Numerous liability suits are active on the link between vinyl-produced molds and respiratory and neurological symptoms among exposed persons. Vinyl has been cited as the interior building material most likely to facilitate the growth of these molds.

Vinyl has been cited as the interior building material most likely to facilitate the growth of toxic molds.



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**Workers and communities are exposed to toxic substances due to PVC production.** In the production of PVC, many thousands of tons per year of the feedstocks ethylene dichloride (EDC) and vinyl chloride monomer (VCM) are released into the workplace and into local environments.

**PVC feedstocks cause cancer and other health impacts.** Both EDC and VCM cause cancer in laboratory animals; VCM is classified as a known human carcinogen and EDC is a probable human carcinogen. Increased risks of liver cancer and brain cancer have been documented among workers exposed to VCM. They are toxic to the nervous system and cause a variety of other impacts on human health. There is preliminary evidence that workers involved in the manufacture of PVC products may have elevated risks of testicular cancer.

**There is no safe VCM exposure level.** Although workplace exposures in U.S. chemical and plastics facilities have been significantly reduced from the levels of the 1960s, there is no threshold below which VCM does not increase the risk of cancer, so current exposures in the U.S. continue to pose cancer hazards to workers. Further, occupational exposure to VCM remains extremely high in some facilities in Eastern Europe and Asia.

**VCM production facilities are major polluters.** Severe contamination of communities and waterways in the vicinity of VCM production facilities has been documented. In Louisiana, significantly elevated levels of dioxins have been found in the blood of people living near a VCM facility, several communities have been evacuated due to VCM contamination of groundwater, and extremely high levels of highly persistent, bioaccumulative by-products attributable to VCM production have been found in local waterways. In Europe, VCM production facilities have caused severe regional contamination with dioxins and other by-products.

**Chlorine production consumes enormous amounts of energy.**

Chlorine production is one of the world's most energy-intensive industrial processes, consuming about 1 percent of the world's total electricity output. Chlorine production for PVC consumes an estimated 47 billion

Even in Europe, where PVC recycling is more advanced than in the United States, less than 3 percent of post-consumer PVC is recycled, and most of this is merely "downcycled."

kilowatt hours per year—equivalent to the annual total output of eight medium-sized nuclear power plants.

**Chlorine production causes mercury pollution.** The mercury-based process for producing chlorine accounts for about a third of world chlorine production. In this process, very large quantities of mercury are released into the environment. Mercury is now a global pollutant that causes severe reproductive, developmental, and neurological impacts at low doses. The vinyl lifecycle is associated with the continuing release of many tons of mercury into the environment each year.

**PVC is extremely difficult to recycle.** Very little PVC is recycled, and this situation is unlikely to change in the foreseeable future. Because each PVC product contains a unique mix of additives, post-consumer recycling of mixed PVC products is difficult and cannot yield vinyl products with equivalent qualities to the original. Even in Europe, where PVC recycling is more advanced than in the United States, less than 3 percent of post-consumer PVC is recycled, and most of this is merely "downcycled" into other products, which means there is no net reduction in the production of virgin PVC. By 2020, only 9 percent of all post-consumer PVC waste in Europe is expected to be recycled, with a maximum potential of no more than 18 percent.

**PVC is one of the most environmentally hazardous consumer materials ever produced.** The PVC lifecycle presents one opportunity after another for the formation and environmental discharge of organochlorines and other hazardous substances. When its entire lifecycle is considered, it becomes apparent that this seemingly innocuous plastic is one of the most environmentally hazardous consumer materials produced, creating large quantities of persistent, toxic organochlorines and releasing them into the indoor and outdoor environments. PVC has contributed a significant portion of the world's burden of persistent organic pollutants and endocrine-disrupting chemicals—including dioxins and phthalates—that are now present universally in the environment and the bodies of the human population. Beyond doubt, vinyl has caused considerable occupational disease and contamination of local environments as well.

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In summary, the feedstocks, additives, and by-products of the PVC lifecycle are already present in global, local, and workplace environments at unacceptably high levels. Efforts to reduce the production and release of these substances should be environmental and public health priorities.

**It is time to phase out PVC building materials.** The hazards posed by dioxins, phthalates, metals, vinyl chloride, and ethylene dichloride are largely unique to PVC, which is the only major building material and the only major plastic that contains chlorine or requires plasticizers or stabilizers. PVC building materials therefore represent a significant and unnecessary environmental health risk, and their phase-out in favor of safer alternatives should be a high priority.

PVC is the antithesis of a green building material. Efforts to speed adoption of safer, viable substitute building materials can have significant, tangible benefits for human health and the environment.

The hazards posed by dioxins, phthalates, metals, vinyl chloride, and ethylene dichloride are largely unique to PVC. It is time to phase out PVC building materials.

## Introduction





## Introduction

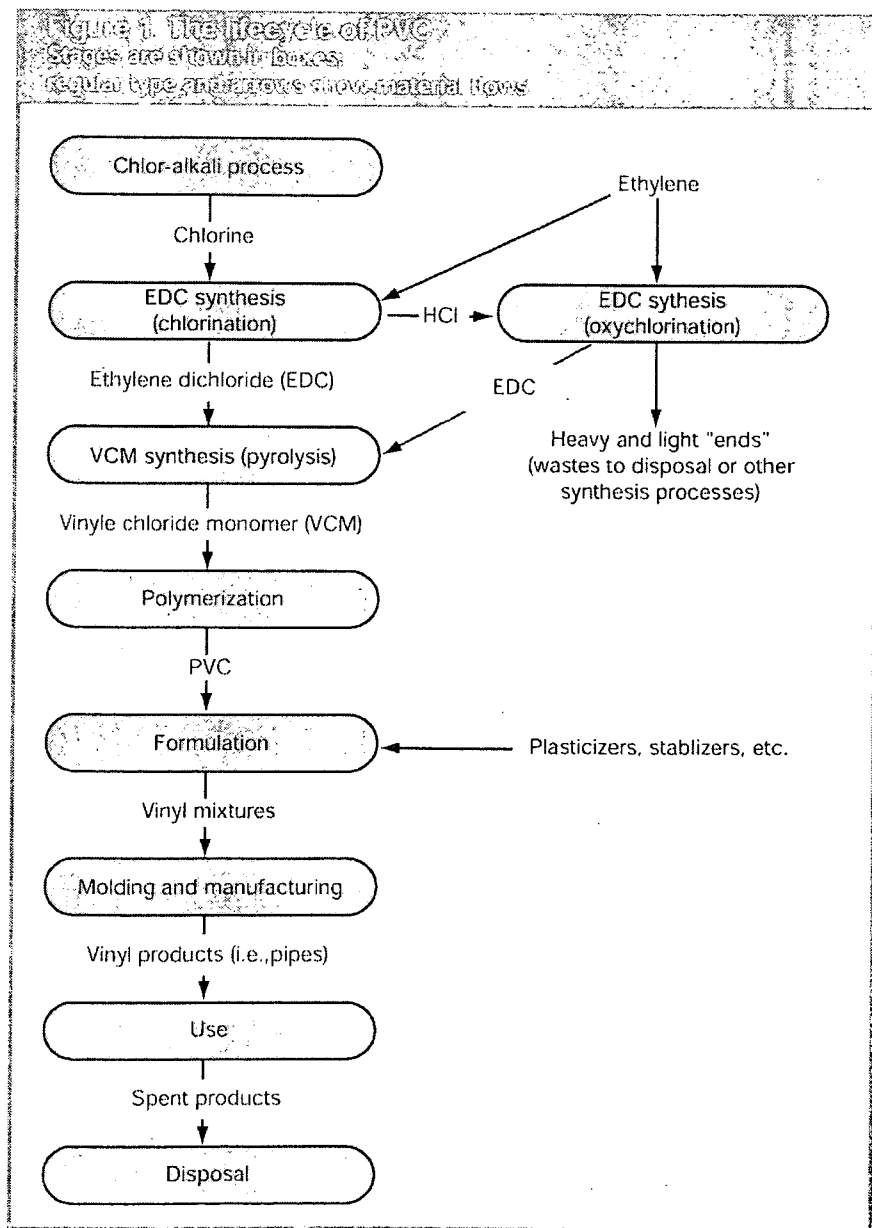
### PURPOSE OF THIS REPORT

The purpose of this report is to present information on the environmental and health hazards associated with the lifecycle of polyvinyl chloride plastic (PVC; commonly known as vinyl). This report is not intended as a complete review of all aspects of the PVC lifecycle; rather, the most important evidence indicating that PVC poses important hazards to health and the environment have been surveyed from a perspective consistent with the precautionary principle. Individual chapters on the manufacture, use and disposal of vinyl products discuss the formation, release, exposure, and health implications of hazardous substances during the manufacture, use, and disposal of vinyl products are considered, as well as energy consumption associated with PVC production. The final chapter presents background information on scientific and economic issues relevant to vinyl and persistent organic pollutants, including a detailed discussion of the environmental hazards of dioxin-like compounds and phthalate plasticizers, two particularly hazardous classes of substances associated with the vinyl lifecycle.

In the United States, building and construction applications account for an estimated 75 percent of all vinyl consumption.<sup>1</sup> In the European Union, 60 percent of vinyl is used in building and construction applications, with an additional 25 percent in appliances, electronics, and furniture.<sup>2</sup> In this report, hazards specific to building and construction uses are highlighted whenever possible; however, many of the hazards of the vinyl lifecycle are general to all PVC uses and will be discussed in that context. Because many of the hazards associated with PVC are global in scale, this report takes an international perspective on vinyl markets and environmental impacts. Further, significant quantities of vinyl and vinyl products are imported, so decisions on building materials in the United States have implications for environmental quality and worker and community health wherever PVC is manufactured.

## TOXIC RELEASES THROUGHOUT THE LIFECYCLE OF PVC

The PVC lifecycle is marked by three major stages—manufacture, use, and disposal (figure 1). Environmental hazards of vinyl production include the formation and release of toxic substances and the consumption of energy and resources in any and all of these steps.





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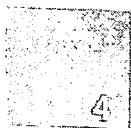
## Manufacture

PVC manufacture is comprised of five major steps—ethylene and chlorine gas production, feedstock production, polymerization, formulation or compounding, and molding.

1. *Ethylene and chlorine gas production*—ethylene gas (purified from petroleum or natural gas) and chlorine gas (synthesized from sea salt by high-energy electrolysis) are two basic materials for vinyl production.
2. *Feedstock production*—ethylene dichloride (EDC, also known as 1,2-dichloroethane) can be produced from chlorine and ethylene by chlorination or oxychlorination. In chlorination, ethylene and chlorine are combined to produce EDC. Hydrogen chloride formed as a by-product in this reaction is then combined with more ethylene to produce additional EDC in a process known as oxychlorination. EDC is then converted into vinyl chloride monomer (VCM; the chemical name of which is chloroethylene), by a reaction called pyrolysis.
3. *Polymerization*—VCM molecules are linked together to yield polyvinyl chloride, typically a white powder.
4. *Formulation or compounding*—pure PVC is mixed with other chemicals—stabilizers, plasticizers, colorants, and the like—to yield a usable plastic with desired properties. In its pure form, PVC is not particularly useful: it is rigid and brittle, and it gradually catalyzes its own decomposition when exposed to ultraviolet light. For PVC to be made into useful products, additives must be mixed with the polymer to make it flexible, moldable, and long lasting.<sup>3</sup> PVC additives include a range of toxic compounds, but the most environmentally important of these are the phthalate plasticizers and metal-based stabilizers—lead, cadmium, organotins, zinc, and other compounds.
5. *Molding*—the formulated plastic is molded to produce the final product, such as a bottle, floor tile, or pipe.

## Usage

The second major stage in the PVC lifecycle is the use of vinyl products. The duration of the product's useful life may be short (PVC packaging, with a lifetime measured in days or weeks) or moderate (PVC floor tiles or roofing materials, which have an average lifetime of 9 to 10 years).<sup>4</sup>





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Environmental hazards during this stage include the release of toxic substances into the indoor or outdoor environment from the vinyl product or during accidental combustion, especially where large quantities of PVC are used, such as vinyl roofing membranes or siding.

### **Disposal**

Finally, after its useful life, the vinyl product is disposed of, typically in incinerators or landfills. Environmental impacts at this stage include the long-term persistence of vinyl products in land disposal facilities, the product being leached of hazardous substances, and the formation and release of unintended combustion by-products when vinyl is incinerated or processed in a secondary smelter for recycling metal products. Only a small portion of vinyl is recycled, a process that can lead to the dispersal of hazardous additives into the environment or a greater range of consumer products.

## **INTERNATIONAL ACTION TO ELIMINATE PVC**

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### **UNEP POPs agreement**

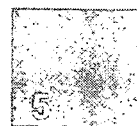
In the fall of 2000, international negotiations were completed on the first legally binding instrument to address global contamination by persistent organic pollutants (POPs).<sup>5</sup> The agreement, which will require each nation to eliminate the production of POPs, represents a fundamental shift from the present control and disposal techniques used to manage chemicals. Although the treaty takes initial action on just 12 pollutants, it includes provisions for additional substances to be addressed in the future. Four of these pollutants are produced in significant quantities during the vinyl lifecycle (table 1).

### **International analyses**

Currently there is considerable international concern and activity to restrict PVC consumption for environmental reasons. In 1995, for example, the American Public Health Association adopted a consensus resolution that hospitals should "reduce or eliminate their use of PVC plastics" wherever feasible due to the global health and environmental impacts of the PVC lifecycle—dioxin generation in particular.<sup>6</sup> In a study of all major packaging materials for the Council of State Governments in the

**Environmental Impacts of PVC**

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**Table 1. Persistent organic pollutants addressed by UNEP's International POPs Agreement**

**Pollutant**

Aldrin  
 DDT  
 Dieldrin  
 Endrin  
 Chlordane  
 Heptachlor  
 Hexachlorobenzene (HCB)\*  
 Mirex  
 Toxaphene  
 Polychlorinated Biphenyls (PCBs)\*  
 Polychlorinated dibenzo-p-dioxins (PCDDs)\*  
 Polychlorinated dibenzo-furans (PCDFs)\*

\* Produced at one or more points during the lifecycle of PVC.

Source: UNEP 1997.

United States, the independent Tellus Institute found that PVC is the most environmentally damaging of all plastics.<sup>7</sup> A lifecycle analysis by the Danish EPA found that the common plastics polyethylene, polypropylene, polystyrene, polyethylene terephthalate (PET), and ethylene-propylene diene synthetic rubber are all clearly preferable to PVC in terms of resource and energy consumption, accident risk, and occupational and environmental hazards, including chemical exposure.<sup>8</sup>

### Restrictions in the EU

Almost all European Union nations have restrictions on uses of PVC. These restrictions address concerns about dioxin exposure, release of phthalate softeners, or the difficulty of recycling and waste disposal. Among the most far-reaching policies are those of Sweden, whose parliament voted in 1995 to gradually eliminate soft and rigid PVC. In 1996, Sweden called for a voluntary industry phase-out of all PVC production. In 1999, it adopted a bill that includes mandatory provisions to eliminate use of PVC with hazardous additives—including phthalates and lead—and to substitute PVC use with other materials wherever feasible. From 1994 to 1999, this program had reduced total PVC use in Sweden by 39 percent.<sup>9</sup>

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Denmark established a national strategy to address the environmental hazards of PVC, including a tax on PVC of \$0.30 U.S. per kilogram, a higher tax on phthalates, a prohibition on the incineration of PVC, and an order to substitute alternative materials for all non-recyclable PVC use. The German Environmental Protection Agency (UBA) has called for an end to the use of phthalates and the gradual phase-out all uses of flexible PVC.<sup>10</sup> Due to the concern for dioxin generation, UBA has also called for a ban on the use of PVC in applications susceptible to fire.<sup>11</sup> The policy in the Netherlands is to reduce the use of PVC in products that are not recycled and to eliminate the use of phthalate plasticizers and lead stabilizers in PVC. The European Union has begun an official process to review the environmental hazards of PVC and to establish appropriate policy measures to safeguard the environment.<sup>12</sup>

### **Restrictions elsewhere in the world**

Not all action on PVC is restricted to Europe. India's Ministry of the Environment and Forests has established rules that ban the incineration of PVC and other chlorinated plastics in medical waste incinerators. Singapore has informed the Secretariat of the Basel Convention on the transboundary movement of hazardous waste that it considers PVC-containing waste and PVC-coated cables to be hazardous waste that are therefore banned from import or export.<sup>13</sup>

### **Restriction on PVC use in construction**

Numerous local and regional governments have specific policies to avoid PVC in construction.<sup>14</sup> In Germany, 274 communities—including Berlin and Bonn—and six states have written policies to phase-out or restrict PVC. The Netherlands' four largest cities—Amsterdam, Den Haag, Rotterdam, and Utrecht—have specifications to avoid PVC whenever possible in construction. Fifty-two cities in Spain have declared themselves "PVC-free," with specific strategies to substitute safer alternatives for PVC construction materials. Basel, Switzerland, has guidelines for the use of environmentally friendly materials, listing PVC as environmentally harmful and a candidate for substitution whenever possible. In Austria, seven of nine states and a large number of municipalities have restrictions on PVC. The city of Linz has reportedly achieved an 85 percent PVC phase-out in public buildings, and the Vienna subway and Vienna Ost hospital were constructed without PVC.

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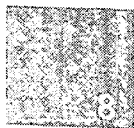
Nearly all of the world's major car manufacturers, including BMW, Daimler-Benz, Ford, General Motors, Honda, Nissan, Opel, Toyota, and Volkswagen AG have policies to reduce or eliminate the use of PVC in automobiles.

Numerous major construction projects have reduced or eliminated PVC entirely. In an effort to utilize green building practices, the Sydney 2000 Olympics established a commitment "to minimizing and ideally avoiding the use of chlorine-based products such as PCBs, PVC, and chlorine-bleached paper."<sup>15</sup> PVC use was eliminated or radically reduced in the construction of the hotel, Olympic village, stadium, and many other structures. Seville's guidelines for the 2004 Olympics specify that "we must avoid the use of PVC in construction, infrastructure, accessories and any other complements in Olympics facilities."<sup>16</sup> The headquarters for the Danish society of Engineers has been built without PVC, as has the new European headquarters for Nike in Hilversum. Many buildings in the United Kingdom, including the new Tate Gallery of Modern Art, have been designed and built to minimize or eliminate PVC use.<sup>17</sup>

Many private firms have also taken steps to restrict or substitute PVC products.<sup>18</sup> The Swedish construction firms HM and Svenska Bostder have announced that they are phasing out PVC use. In Japan, the electronics manufacturers AEG, Electrolux, Matsushita, Ricoh, Sharp, Sony-Europe, and Vorwerk have PVC phase-out policies. German Telekom, Nippon, and Sumitomo Electric Industry have policies to avoid PVC use in cable manufacture. The furniture and décor manufacturers and retailers Eco AB, EWE Kuechen (Austria), IKEA, and Innarps AB have policies to avoid PVC products. In transportation, nearly all of the world's major car manufacturers, including BMW, Daimler-Benz, Ford, General Motors, Honda, Nissan, Opel, Toyota, and Volkswagen AG have policies to reduce or eliminate the use of PVC in automobiles.

### **PVC restrictions in toys**

Particularly urgent and widespread action has focused on PVC toys, due to concern for exposure of children to phthalate plasticizers in flexible PVC. In the late 1990s, government ministries in Denmark and the Netherlands found that substantial quantities of phthalates are released from PVC into saliva from vinyl teething rings and chew toys. As a result, these countries, along with ministries in Austria, Belgium, Finland, France, Germany, Greece, Italy, Norway, Spain, and Sweden, sought bans on the use of soft PVC in toys. In 1997, a number of European toy retailers and manufacturers suspended sales of PVC teething rings or announced plans



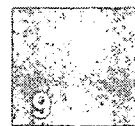
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to eliminate all vinyl from their toy lines. In late 1998, when a wave of publicity on the issue hit the U.S. press, Mattel, Toys-R-Us, and several other U.S. toy makers and retailers announced that they would stop selling certain vinyl toys.<sup>19</sup> Subsequently, the U.S. Consumer Product Safety Commission called on the toy industry to voluntarily stop making vinyl chewing toys that contained phthalates.<sup>20</sup> In 1999, the European Commission finalized an emergency ban on six phthalate plasticizers found in soft PVC toys. Although toys represent a small fraction of total PVC consumption, the trend away from vinyl use in toys is significant for the entire industry. As one plastics industry spokesman commented, "In the long run, the industry will go the way toys go."<sup>21</sup>

## PVC AND THE CASE AGAINST ORGANOCHLORINES

EDC, PVC, VCM, and the by-products formed during the vinyl lifecycle are members of a large class of problematic chemicals called organochlorines—organic (carbon-based) substances that also contain one or more atoms of chlorine. The debate over PVC takes place in the context of broader concern about the class of organochlorines—regarded by many as the most environmentally problematic class of synthetic substances.<sup>22</sup> PVC is the only major plastic used in buildings that contains chlorine. Chlorine-free plastics include polyethylene (PE), polypropylene (PP), polyethylene terephthalate (PET), acrylonitrile-butadiene-styrene (ABS) copolymer, ethylene vinyl acetate (EVA), and numerous others. Polyurethane, polycarbonate, and epoxy resins are chlorine-free plastics that are currently manufactured via the organochlorine intermediates chlorohydrin, epichlorohydrin, phosgene, and propylene, but technologies are being developed to produce these plastics through chlorine-free routes.<sup>23</sup>

The proper course of action for addressing organochlorines is controversial. Some organizations and analysts, including the American Public Health Association and the International Joint Commission (a binational advisory body of the United States and Canadian governments charged with protection of the Great Lakes ecosystem), have called for a gradual phase-out of all uses of chlorine and organochlorines. Others, including the chemical industry and the Society of Toxicologists, have advocated continuing the current system of chemical-by-chemical regulation.<sup>24</sup>



Of the 12 POPs addressed by United Nations Environmental Programme (UNEP), all are organochlorines, and four are produced by the PVC lifecycle.

Decisions about the use of PVC in building materials do not require the proper course of action on all organochlorines to be resolved. The question of vinyl should be seen, however, in the context of concern about the class of chemicals of which PVC is perhaps the most important member. Vinyl and its feedstocks have the largest production volume, by far, of all organochlorines. Further, a vast variety of other organochlorines are produced in considerable quantities during the lifecycle of vinyl. Many of these by-products are known to be hazardous; many more have not been specifically identified or evaluated for their environmental behavior and toxicity, and an understanding of the general characteristics of organochlorines is relevant to predicting their hazards.

Concern about organochlorines began with the recognition that they tend to dominate all major lists of "priority pollutants." For example, of the 12 POPs addressed by United Nations Environmental Programme (UNEP), all are organochlorines, and four are produced by the PVC lifecycle (see table 1). Of the 11 chemicals on the International Joint Commission's Critical Track of hazardous pollutants in the Great Lakes, eight are organochlorines, as are 168 of the 362 Great Lakes contaminants on the IJC's Secondary Track.<sup>25</sup> Organochlorines are prominent on EPA's list of common groundwater pollutants and of contaminants at hazardous waste sites, and they constitute the majority of the list of known endocrine disrupting chemicals.<sup>26</sup>

### **Systematic problems with organochlorines**

Further analysis has revealed why organochlorines are so problematic. Organochlorines tend to have several characteristics, all of which derive from fundamental chemical properties of the chlorine atom. The same properties that make chlorine and organochlorines useful in industrial applications, in fact, are responsible for their environmental hazards.

*Reactivity of chlorine.* Chlorine gas is extremely reactive, combining quickly and randomly with any organic matter it contacts. This property makes it an effective bleach, disinfectant, and chemical feedstock, but also results in the generation of a diverse mixture of by-products, typically containing hundreds or thousands of organochlorines—including dioxins—whenever chlorine is used.<sup>27</sup>

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*Persistence.* The chlorine atom is extremely electronegative, which means it exerts a strong pull on the electrons it shares with carbon atoms in an organochlorine—significantly stronger than the hydrogen atom it usually replaces. The addition of chlorine to organic molecules therefore changes the chemical stability of the resulting substance—often stabilizing but sometimes destabilizing it, depending on the structure of the parent compound. In most cases, the resulting organochlorine is far less reactive than the original substance; organochlorines that do break down usually degrade into other organochlorines, which may be more persistent and toxic than the original substance. Stability makes organochlorines useful as plastics, solvents, and refrigerants—applications for which long-life and fire-resistance are virtues. This same property, however, makes these organochlorines persistent in the environment and therefore likely to accumulate and become globally distributed.

In some cases, organochlorines become more unstable and reactive than the parent compound, making them useful as chemical intermediates. But this property also makes them more easily converted in the body to toxic and reactive metabolites (other organochlorines), which can then proceed to damage DNA or other essential molecules in cells.<sup>28</sup> Chlorine's impact on the stability of organic molecules thus has one of two opposite effects, depending on the structure of the parent compound—and both are problematic from an environmental health perspective.

*Bioaccumulation.* One factor that determines the solubility of a substance in water or fat is its molecular size; the larger a molecule, the more it disrupts interactions among water molecules and the greater the tendency for the substances to be nondissolvable in water. The chlorine atom is very large—several times larger than an atom of carbon, hydrogen, or oxygen—so chlorination significantly increases the size of organic molecules and as a result almost invariably increases solubility in fats and oils. The increase in fat solubility applies to the chlorination of virtually any organic substance, and increases with each chlorine atom added.<sup>29</sup> Thus, for example, tetrachloroethylene, hexachlorobenzene and octachlorodibenzofuran, are about one hundred, one thousand, and one billion times more oil-soluble, respectively, than their chlorine-free analogs (figure 2). Oil-solubility makes organochlorines useful as solvents

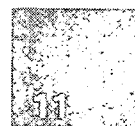
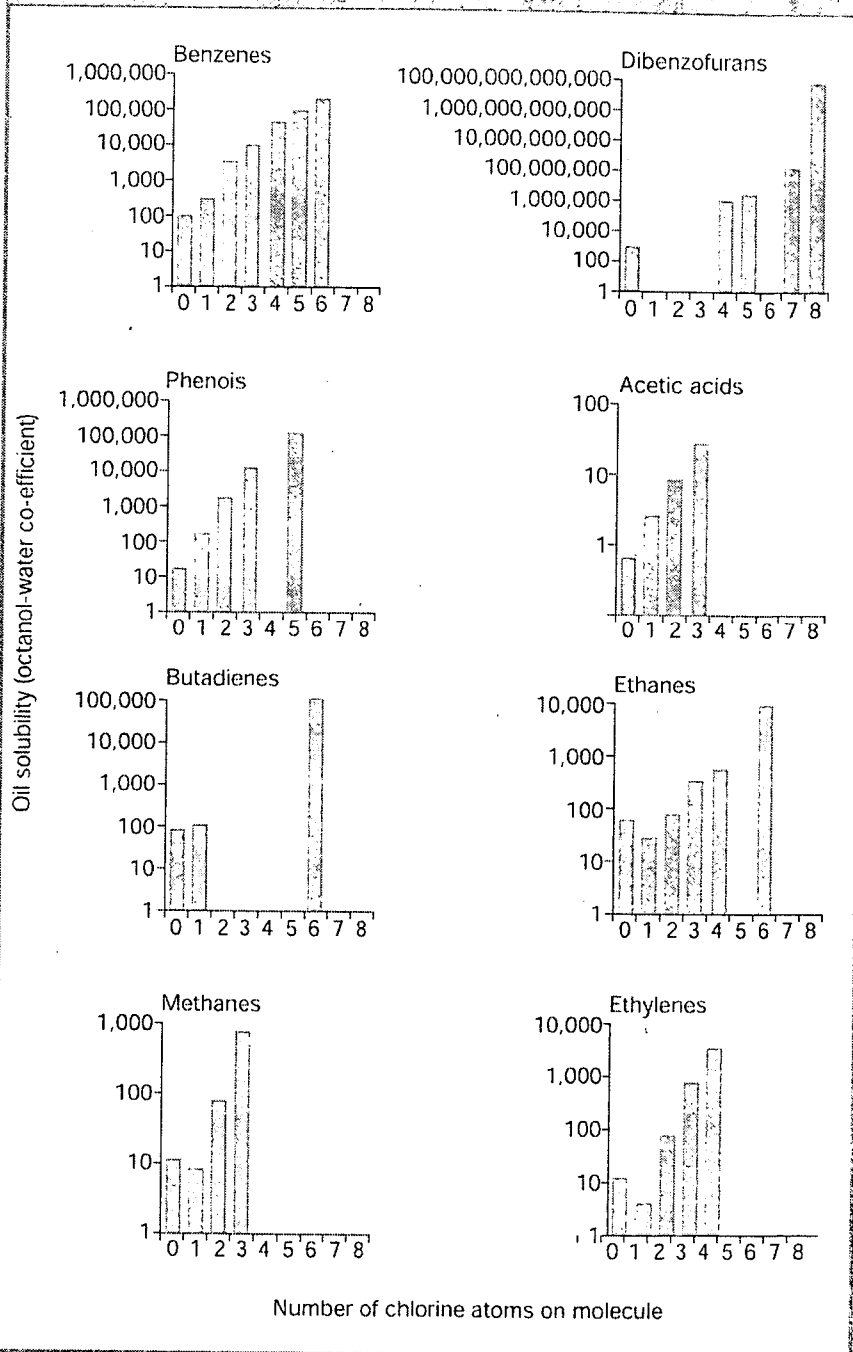


Figure 2 Effect of chlorine on oil solubility and bioaccumulation on organic chemicals



Note: In all groups, chlorination increases the tendency of a chemical to dissolve fats and oils, and each chlorine atom has a greater effect. Blank cells indicate no data available.

Source: HSDB 1997.



and dielectric fluids, but it is directly responsible for the tendency to bioaccumulate.

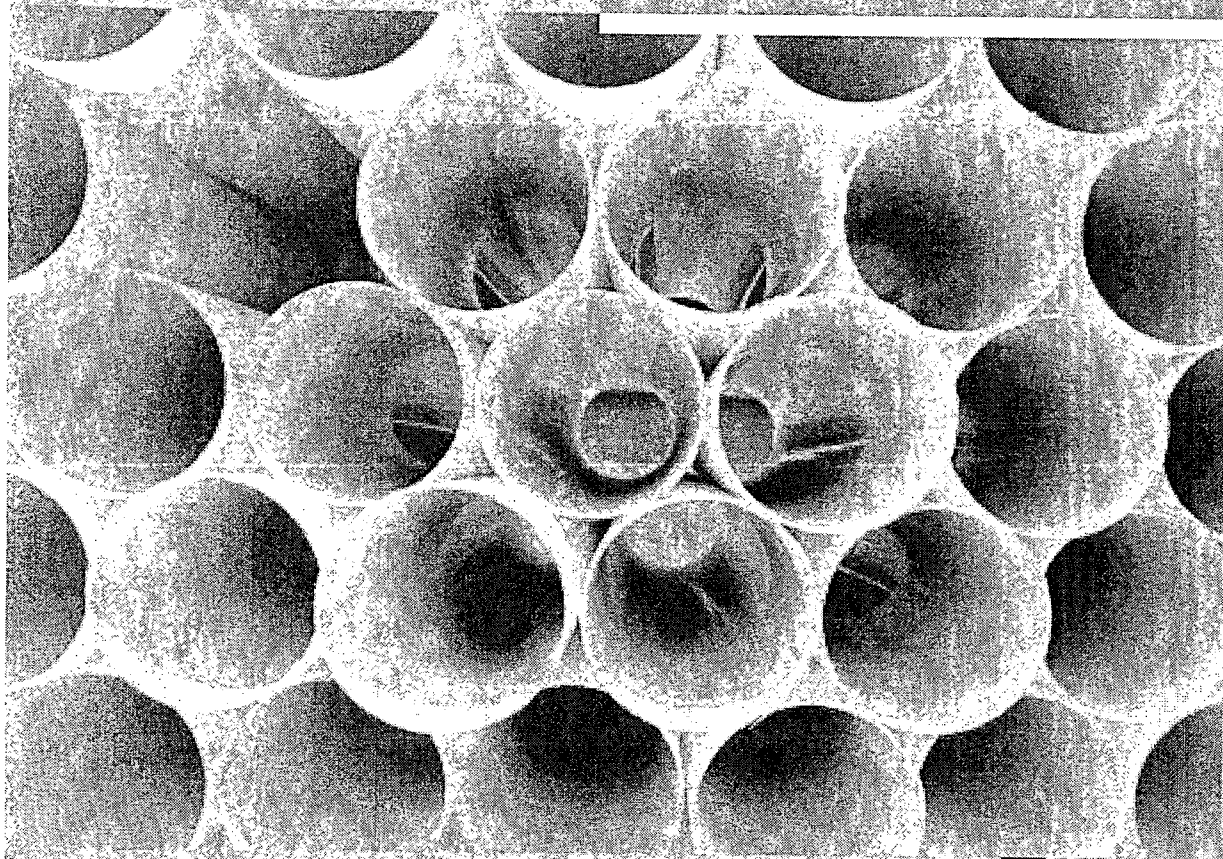
*Toxicity.* Organochlorines tend to be overwhelmingly toxic. The American Public Health Association has concluded that "virtually all organochlorines that have been studied exhibit at least one of a range of serious toxic effects, such as endocrine dysfunction, developmental impairment, birth defects, reproductive dysfunction and infertility, immunosuppression and cancer, often at extremely low doses, and many chlorinated organic compounds...are recognized as significant workplace hazards."<sup>30</sup> According to a comprehensive independent review of thousands of individual organochlorines, chlorination of organic chemicals "is almost always associated with an increase in the toxic potential. Only rarely does chlorination produce no increase or even a decrease in effects. This observation applies for all kinds of toxic effect (acute, subchronic, and chronic toxicity; reproductive toxicity; mutagenicity; and carcinogenicity)."<sup>31</sup> The general toxicity of organochlorines makes them useful as pesticides and antibiotics, but also hazardous to humans and wildlife once they enter the environment.

## Notes

1. Geiser 2000.
2. European Commission 2000.
3. Tukker et al. 1995.
4. Schneider and Keenan 1997.
5. United Nations Environment Programme 2000.
6. APHA 1996.
7. Tellus Institute 1992.
8. Christensen et al. 1990. PVC was not judged demonstrably inferior under certain criteria (such as energy use and accident potential during manufacture) to polyurethane, acrylonitrile-butadiene-styrene, and aluminum.
9. Kerf 2000; Greenpeace International 2000.
10. European Commission 2000.
11. UBA 1992.
12. European Commission 2000.
13. Greenpeace International 2000.
14. Greenpeace International 2000.
15. Quoted in Greenpeace International 2000.
16. Quoted in Greenpeace International 2000.
17. Greenpeace International 2000.
18. Greenpeace International 2000.
19. Warren 1998; *New York Times* 1998.
20. Mayer 1998.
21. Warren 1998.
22. Thornton 2000; Collins 2001; International Joint Commission 1992; APHA 1994.
23. For a discussion of chlorine-free synthesis technologies, see discussion and references in Thornton 2000.
24. Karol 1995.
25. Great Lakes Water Quality Board 1987.
26. Burmaster and Harris 1982; Miller et al. 1991; Guillette and Crain 1999.
27. See discussion and references in Thornton 2000.
28. Henschler 1994.
29. Solomon et al. 1993.
30. APHA 1994.
31. Henschler 1994.

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## PVC Production





## PVC Production

### PRODUCTION OF CHLORINE

The PVC lifecycle begins with the production of chlorine gas in the chlor-alkali process. Electricity is passed through a solution of brine to produce sodium hydroxide (also called alkali or caustic soda) and chlorine gas in a fixed ratio of 1.1 to 1. Because chlorine gas and sodium hydroxide react with each other on contact, the key to the process is to separate immediately the chlorine from the alkali in a specially designed electrolytic chamber, called a cell. There are three types of chlor-alkali cells in use, which differ in the ways that chlorine and alkali are separated from each other.

The mercury process, the oldest and most energy-intensive of the three processes for chlorine production, involves two connected cells. In the first cell, salt is split into chlorine gas and sodium at the cell's positive terminal (called the anode); the sodium forms an amalgam with a layer of liquid mercury, which then flows into another cell, where it reacts with water to form sodium hydroxide and hydrogen gas. The mercury process is banned in Japan, but 35.5 percent of chlorine production worldwide is by this method, with 14 percent of chlorine in North America and 65 percent of that in Western Europe produced by this technology as of 1994. In Western Europe, the Oslo-Paris Commission on the Northeast Atlantic has recommended that mercury cells be phased out, so the proportion of mercury-related chlorine is expected to decline.<sup>1</sup>

In the asbestos diaphragm process, brine enters the cell and is split at the anode, yielding chlorine gas and sodium ions. The ions then flow through a semi-permeable asbestos barrier to the other pole, where they react with water to form sodium hydroxide and hydrogen gas. Chlorine, which cannot pass through the membrane, remains near the anode. The

diaphragm method was developed after the mercury process and, as of 1994, accounted for 77 percent of all chlorine production in the United States and 25 percent in Europe.<sup>2</sup>

The remaining 7 percent of chlor-alkali production is based on the membrane process, the most recently developed of the three methods. The membrane technique is similar to the diaphragm process, except that a synthetic membrane rather than asbestos is used to separate the compartments in which chlorine and alkali are formed. The membrane process uses slightly less energy and yields products of higher purity than the other kinds of cell, but retrofitting a chlorine plant with membranes is expensive. Because most chlor-alkali plants in the United States and Europe were built decades ago, few use the membrane process. But most new facilities—particularly those in Asia and Latin America—are now constructed with it.<sup>3</sup>

The world chlor-alkali industry produced nearly 39 million metric tons of chlorine in 1997; 27 percent of that was made in the United States. There are 42 chlor-alkali facilities in the United States, but more than 70 percent of production capacity is located at just 12 large plants in the Gulf Coast region of Louisiana and Texas.<sup>4</sup> Because vinyl accounts for more than 40 percent of all chlorine consumption, it is reasonable to estimate that the same proportion of the environmental impacts of chlorine production—releases of toxic substances and energy demand—is associated with the vinyl lifecycle.

### **Dioxin and other organic by-products**

From the moment that chlorine gas is formed in the chlor-alkali cell, it will react with any organic matter present to form organochlorines. For this reason, manufacturers purify raw materials and equipment surfaces carefully to remove as much organic material as possible. Nevertheless, carbon-containing substances remain as trace impurities—in plastic materials or from the graphite electrodes used in some types of chlor-alkali cells.<sup>5</sup> Chlorine combines with these organic contaminants to form persistent organochlorine by-products, such as HCB and hexachloroethane (HCE), which are found in the chlorine product itself.<sup>6</sup> Chlorine gas can also be contaminated with PCBs, octachlorostyrene (OCS), and tetrachlorobenzene. The concentrations are

Chlorine gas produced each year for vinyl production carries between 1,400 and 7,200 pounds of highly persistent and toxic organochlorine by-products — including HCB, hexachloroethane (HCE), PCBs, OCS, tetrachlorobenzene—into the world's economy.

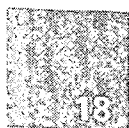
Severe contamination of fish and sediments with OCS—an extremely persistent, bioaccumulative POP—has been documented near eight North American chlorine producers.

moderate—40 to 210 parts per billion (ppb)<sup>7</sup>—but the quantities are significant: based on the levels found, the chlorine gas produced each year carries between 1.6 and 8.2 tons of these highly persistent and toxic by-products into the world's economy.<sup>8</sup> Based on an attributable fraction of 40 percent, the chlorine used for vinyl contains between 1,400 and 7,200 pounds of these substances annually.

Much greater quantities of organochlorine contaminants are deposited in chlorine production wastes. Swedish researchers have identified high concentrations of dioxins and furans<sup>9</sup> in the sludges from spent graphite electrodes used in chlor-alkali cells,<sup>10</sup> and high levels of polychlorinated dibenzofurans have been found in the blood of Swedish chlor-alkali workers.<sup>11</sup> The levels were up to 650 ppb, with TEQ values up to 28 ppb. (Because dioxin-like compounds cause toxicity through a common mechanism, mixtures of these substances can be expressed relative to the toxicity of TCDD, the most toxic dioxin, as TCDD-equivalents (TEQ). To calculate the TEQ value for a mixture, the quantity of each substance is multiplied by its toxicological potency relative to TCDD, and the TEQ is the sum of these weighted quantities. A mixture with a calculated TEQ of 1 microgram is expected to have toxicity equal to 1 microgram of TCDD.)

Severe contamination of fish and sediments with OCS—an extremely persistent, bioaccumulative POP—has been documented near eight North American chlorine producers. Additionally, large-scale OCS contamination of sediments in Lake Ontario has been traced to disposal of spent chlor-alkali electrodes.<sup>12</sup> OCS is now a global contaminant, with considerable levels found in the Canadian arctic—and chlor-alkali manufacture is considered an important source of that contamination.<sup>13</sup>

As a result of these problems, all chlor-alkali plants in North America and many in Europe replaced graphite electrodes with titanium substitutes during the 1970s and 1980s—a move that industry and government assumed eliminated the formation of organochlorine by-products. But recent data indicate that even the most modern chlor-alkali plants produce dioxin-like compounds. With graphite eliminated, traces of organic chemicals are still present, primarily from plastic pipes and valves that release small quantities of their materials into the cell. A 1993 study by



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Swedish scientists found dioxins and furans in the sludge and plastic piping from a modern chlor-alkali plant with titanium electrodes at levels near 5 ppt (TEQ).<sup>14</sup> Subsequent Swedish research found significant quantities of chlorinated dibenzofurans in the sludge from a chlor-alkali plant with titanium electrodes, apparently due to chlorination of organic compounds in the rubber linings of the cell.<sup>15</sup> In 1997, the UK Environment Agency confirmed that a chlor-alkali plant owned by ICI Chemicals and Polymers, which replaced its graphite electrodes around 1980, continues to release dioxins in its wastewater.<sup>16</sup>

### Mercury releases

Most of the mercury used in mercury chlor-alkali cells is recycled, but significant quantities are routinely released into the environment via air, water, products, and waste sludges. In the 20th century as a whole, chlor-alkali production has been the largest single source of mercury releases into the environment.<sup>17</sup> As recently as the 1980s, the chlorine industry was second only to fossil fuel combustion as a mercury source in Europe.<sup>18</sup>

Many mercury-cell plants have been retired in the past two decades, and controls on existing plants have improved, but chlor-alkali facilities remain a source of mercury pollution. The chlorine industry is the largest mercury consumer in the United States; it is presumably even more important in Europe, where the mercury cell process is more common.<sup>19</sup> According to the Chlorine Institute (an industry organization) the chlor-alkali industry in the United States consumes 176,769 pounds of mercury per year.<sup>20</sup> By definition, materials consumed are not recycled but are released directly to the environment, into wastes, or in the product itself. Without providing documentation, the Vinyl Institute has argued that only 20 percent of the chlorine produced by the mercury process in the United States is used to produce PVC.<sup>21</sup> Based on these two figures, vinyl manufacture in the United States alone is associated with the release of more than 35,000 pounds (about 16 metric tons) of mercury into the environment each year.

The U.S. industry's figures probably significantly underestimate actual mercury releases. More detailed estimates, derived by superior mass-balance accounting methods, are available based on studies conducted



Table 2. Mercury releases from the world chlor-alkali industry, 1994.

	Metric tons of mercury per year <sup>1</sup>	PVC attributable portion <sup>2</sup>
Total consumption	229.8	91.9
Air emissions	26.3	10.5
Discharges to water	2.8	1.1
Contaminants in products	5.5	2.2
Disposed on land	157.8	63.1
Unaccounted for	36.0	14.4

1. Assuming 39 million metric tons per year of chlorine production worldwide, of which 35.5 percent was produced by the mercury process.

2. Assuming that PVC accounts for 40 percent of chlorine consumption worldwide and that an equal fraction of the chlorine produced in mercury cells is used for PVC, the Vinyl Institute has argued that the attributable fraction for mercury is 20 percent in the United States.

Note: These data are based on mass balances prepared by the chlorine industry for facilities in Europe and may not accurately represent global averages.

Source: Ayres 1997.

by Euro-Chlor, the trade association of the European chlorine industry.<sup>22</sup> This information indicates that the world chlor-alkali industry consumed about 230 tons of mercury in 1994; this is the quantity not recycled but lost from production processes each year. Exactly where the mercury goes remains controversial, but if we extrapolate from the Euro-Chlor estimates, about 30 tons were released directly into the air and water, 5 tons remained as a contaminant in the product, more than 150 tons were disposed on land, and 36 tons could not be accounted for (table 2). Based on these figures and an attributable fraction of 40 percent, the PVC lifecycle is associated with the consumption of 92 metric tons of mercury (202,400 pounds) per year, of which the majority is released into air, water, or landfills. If we use the Vinyl Institute's U.S.-based estimate that 20 percent of the chlorine produced by the mercury process is used to produce PVC, production of chlorine for vinyl would account for the release of 46 tons per year of mercury each year. The actual worldwide totals are likely to be even higher since the well-regulated facilities of Europe are not likely to be representative of those in other regions of the world.

Mercury is an extremely toxic, bioaccumulative global pollutant. Mercury compounds cause irreversible health damage to wildlife and humans—especially to developing children, resulting in birth defects, impaired neurological development, kidney damage, and severe neurological destruction.<sup>23</sup> The most tragic and infamous example of mercury

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pollution happened in Minimata, Japan, where the Chisso Chemical company routinely dumped mercury-contaminated waste into the local bay from the 1930s to the 1960s. Fish in Minimata Bay bioaccumulated mercury to levels 40 to 60 times higher than those in nearby ecosystems, and the local population—among whom a diet of fish played a key role—suffered high mercury exposures. In the early 1950s, symptoms of chronic mercury poisoning, including neurological toxicity, paralysis, coma, and death began to appear in adults in the community, and a horrifying outbreak of severe birth defects and mental retardation occurred in children. Ultimately, mercury poisoning killed hundreds and injured more than 20,000 people in the Minimata area.<sup>24</sup> Chlor-alkali production is not traditionally assumed to have been the source of the Chisso's mercury releases because the company had been using mercury as a catalyst in fertilizer production since the 1930s. As one history of the event points out, however, Chisso began using the mercury process to make chlorine for PVC plastic in 1952. In 1953, symptoms of mercury poisoning began to appear in the local population, and over the next four years the number of victims correlated with Chisso's growing production volume of vinyl chloride.<sup>25</sup> This pattern suggests that mercury releases from the chlor-alkali process are likely to have played a role in the Minimata epidemic.

Today, mercury exposure remains a major environmental health problem. According to a recent report by the U.S. National Academy of Science, "Individuals with high [mercury] exposure from frequent fish consumption might have little or no margin of safety—in other words, exposures of high-end consumers are close to those with observable adverse effects. Those most at risk are children of women who consumed large amounts of fish and seafood during pregnancy. The committee concludes that the risk to that population is likely to be sufficient to result in an increase in the number of children who struggle to keep up in school and who might require remedial classes or special education."<sup>26</sup>

Mercury cells are now banned in Japan and are gradually being phased out in the United States and Europe as well, but releases of mercury remain a problem. In the 1980s, for instance, a major British chlor-alkali facility was found to be discharging up to 100 kilograms per day of mer-

The PVC lifecycle is associated with the consumption of 92 metric tons of mercury (202,400 pounds) per year, of which the majority is released into air, water, or landfills.



The global chlor-alkali industry consumes about 117 billion kilowatt-hours of electricity each year, equivalent to the annual power production of about 20 medium-sized nuclear power plants.

cury into local waterways; more than a decade later, mercury levels in the sediment remained extremely high.<sup>27</sup> In Italy, elevated levels of mercury in air, soil, and plant tissues have been found in the vicinity of a mercury-based chlor-alkali plant owned by the Solvay Company.<sup>28</sup> In India, a 1990 study of waterways around a chlorine facility documented severe mercury contamination of fish and sediments.<sup>29</sup>

### Major energy consumption

Chlorine production requires enormous amounts of energy. Chlor-alkali electrolysis is one of the most energy-intensive industrial processes in the world. The production of one ton of chlorine requires about 3,000 kilowatt-hours of electricity, and the global chlor-alkali industry consumes about 117 billion kilowatt-hours of electricity each year.<sup>30</sup> This quantity is about 1 percent of the world's total demand for electricity,<sup>31</sup> costs about \$5 billion per year,<sup>32</sup> and is equivalent to the annual power production of about 20 medium-sized nuclear power plants.<sup>33</sup> As a major energy consumer, chlorine chemistry contributes considerably to all the environmental problems—global warming, air pollution, acid rain, mercury emissions, generation of radioactive and other wastes from the mining, processing, and consumption of nuclear fuels, and so on—that are associated with energy production.

Based on an attributable fraction of 40 percent of chlorine demand, the chlorine consumed in vinyl production is associated with electricity consumption of approximately 47 billion kilowatt-hours per year. On a per mass basis, production of chlorine to make one ton of PVC consumes about 1,800 kilowatt-hours of electricity, based on the fact that pure PVC is 59 percent chlorine by weight. Additional energy is consumed in the chemical synthesis of EDC, VCM, and PVC and in the production of additives in the vinyl product. An estimate of the total energy consumption required for the manufacture of PVC is beyond the scope of this document.

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## SYNTHESIS OF EDC AND VCM

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### Releases of EDC and VCM carcinogens

Large quantities of EDC and VCM are released directly into the environment during the production of feedstocks for PVC. Because at least 95 percent of the world's annual production of 24 million tons of VCM goes into PVC, these releases are almost entirely attributable to vinyl products.

Undoubtedly, extremely large quantities of EDC and VCM are released into the air and water each year. As part of the U.S. Toxics Release Inventory (TRI), manufacturers of PVC and its feedstocks self-reported emissions of 887,000 and 798,000 pounds of VCM and EDC, respectively, directly into the environment in 1998; an additional 2 million pounds of VCM and 27 million pounds of EDC were reported sent to sewage treatment plants or off-site waste facilities.<sup>34</sup> These figures may significantly underestimate actual releases, however, because of widely recognized problems with the TRI database. Reported emissions are not based on actual monitoring of releases, and estimation methods vary greatly among facilities. Most importantly, TRI release estimates are self-reported by the industry and are thereby subject to no independent verification.

More valid figures come from estimates made by the Norwegian government in 1993. Based on a detailed mass balance conducted at a Norwegian facility, specific estimates of per-ton releases of EDC and VCM from vinyl manufacture were made (table 3). Extrapolating these estimates using 1990 vinyl production figures,<sup>35</sup> we can calculate that the PVC industry releases at least 100,000 tons each of EDC and VCM into the air each year—plus more than 200 tons of EDC and 20 tons of VCM into surface water. Worldwide VCM production has increased by about 50 percent in the past decade,<sup>36</sup> which increases the associated estimates of total releases by a similar fraction. The actual total may be even higher since this estimate was extrapolated from emissions at a single facility in Norway: manufacturers in many other nations have less advanced pollution control equipment and less careful plant operation than this relatively modern, well-regulated facility.

Table 3. Releases of EDC and VCM in PVC production stages: Norwegian government estimates, 1993				
Product	Grams released per ton of product			
	EDC to air	EDC to water	VCM to air	VCM to water
EDC synthesis (1 ton)	—	7	—	—
VCM synthesis (1 ton)	5000	1	1000	1
PVC polymerization (1 ton)	—	—	5100	—
— Indicates releases <1 g/ton.				
Source: SFT 1993.				

EDC and VCM are not particularly persistent—but both are highly toxic. Releases of these compounds therefore pose the greatest hazards for communities and ecosystems near EDC/VCM manufacturing facilities. The facility studied in Norway, for instance, releases 40 to 100 tons of EDC each year directly into the local atmosphere.<sup>37</sup> In the United States, some 12.5 million people are exposed to EDC emissions from chemical manufacturing facilities, according to the National Institute for Occupational Safety and Health. Workers in plants that manufacture PVC or its feedstocks receive the highest exposures to these compounds in workplace air—81,000 U.S. workers are regularly exposed to vinyl chloride, while 77,000 are exposed to EDC.<sup>38</sup>

According to the International Agency for Research on Cancer and the U.S. National Toxicology Program, VCM is a known human carcinogen, and EDC is a probable human carcinogen. Studies of workers exposed to VCM have shown an unambiguous increase in liver cancer. Four out of five studies also report an increased risk of brain cancer that is statistically significant in a combined analysis.<sup>39</sup> Both EDC and VCM cause a variety of other toxic effects, including immune suppression, liver damage, neurological toxicity, and testicular damage.<sup>40</sup>

Since the carcinogenicity of VCM was established, government regulations have required considerable reductions in worker VCM exposure. In the United States, workplace VCM levels within the 1–5 ppb range are now required—orders of magnitude lower than typical concentrations of the 1950s and 1960s—but much higher levels continue to occur in facili-

ties elsewhere.<sup>41</sup> For example, a recent survey found that workers in Asia and Eastern Europe are typically exposed to VCM at levels up to 1,000 times the typical U.S. concentrations. In China, the air in dormitories for plastics industry workers and their families contains VCM levels that exceed the permissible workplace level in the United States.<sup>42</sup>

Although occupational exposure to EDC and VCM has declined significantly in the United States, even the much lower levels that now characterize the domestic vinyl industry remain a matter of concern, because there appears to be no safe dose of these compounds. The mechanisms by which EDC and VCM cause cancer have been elucidated, and it is now clear that both substances are genotoxic—causing irreversible damage to DNA. Indeed, VCM has been shown to form chemical bonds with DNA, leading to mutations that abolish natural controls over cell differentiation and proliferation.<sup>43</sup> Currently accepted biological theory indicates that mutations in a single cell can result in the development of a malignant tumor; similarly, a single molecule of a genotoxic substance can damage DNA. Carcinogens such as VCM therefore are not likely to have a threshold below which they do not increase the risk of cancer. That is, any exposure to this carcinogen poses some risk of cancer, and the magnitude of the risk increases with the level of exposure.<sup>44</sup> The same is true of other health impacts mediated by DNA damage, including certain birth defects and genetic diseases. Thus, reduced levels of EDC and VCM in U.S. PVC production facilities reduce but do not eliminate the occupational health risks from these chemicals.

The health effects of community EDC and VCM exposure remain largely unstudied. It is clear, however, that severe environmental contamination and social disruption have occurred in several communities near EDC and VCM production facilities. As an example, Reveilletown, Louisiana, was once a small African-American community adjacent to a EDC/VCM facility owned by Georgia-Gulf. In the 1980s, after a plume of vinyl chloride in groundwater began to seep under homes in the area, a number of residents complained of health problems and brought a lawsuit against the company. In 1988, Georgia-Gulf agreed to an out-of-court settlement that provided for the permanent evacuation of the community but sealed the court records and imposed a gag order on the plaintiffs. One hundred six residents were relocated and Reveilletown has since been demolished.<sup>45</sup>

EDC and VCM are genotoxic—causing irreversible damage to DNA—and are not likely to have a threshold below which they do not increase the risk of cancer.

The next year, as concern about air and groundwater pollution grew around Dow Chemical's EDC/VCM facility five miles from Reveilletown in the small town of Morrisonville, near Plaquemine, Louisiana, Dow began to buy out and relocate citizens there in a pro-active program to avoid exposure, liability, and bad press. Morrisonville, too, is now all but abandoned.<sup>46</sup> On the other side of the state, in Lake Charles, Louisiana, PPG and Vista Chemical manufacture EDC and VCM, which, along with by-products of their synthesis, now contaminate water and sediments in the Calcasieu Estuary.<sup>47</sup> Residents here continue to occupy their homes, drink local water, and eat fish from the area's polluted bayous. Because many EDC/VCM manufacturing facilities are located in communities with poor and/or minority populations, this stage of the PVC lifecycle has considerable environmental justice impacts.

#### **Formation of PCBs and other organochlorine by-products**

EDC/VCM synthesis generates large quantities of persistent, bioaccumulative by-products. EDC is made in two ways: ethylene is chlorinated with chlorine gas, or ethylene is oxychlorinated with hydrogen chloride that has been formed as a waste in other synthesis processes. Most EDC producers use both methods in a linked cycle, since chlorination of ethylene generates hydrogen chloride as a by-product, which can then be used in oxychlorination. Both processes yield a complex mixture of reaction products, which are then distilled to yield three batches of materials: the distilled EDC product, the light ends (those substances more volatile than EDC), and the heavy ends (less volatile than EDC). The waste quantities are quite large—about two kilograms each of heavy and light ends for each ton of EDC produced. Based on these figures, world EDC synthesis by the oxychlorination process produces at least 30,000 tons per year each of light and heavy ends.<sup>48</sup>

In general, the heavy ends are discarded and the light ends reprocessed in other chemical reactions. EDC goes on to be pyrolyzed—heated in the absence of oxygen—to yield VCM. By-products formed in this process include chlorinated ethanes, chlorobenzene, chlorobutadiene, ethylenes, methanes, and large amounts of complex but uncharacterized waste tars.<sup>49</sup> According to industry sources, the total amount of chemical wastes produced in the various processes involved in EDC/VCM synthesis is

estimated as between 3 to 10 percent of the VCM yield—a staggering 570,000 to 1.9 million tons of by-products each year.<sup>50</sup>

The heavy ends contain most of the persistent and toxic by-products. No academic or government studies have sought to identify all the compounds present in these wastes, but there are data from industry and environmental groups. In 1990, Dow Chemical analyzed its EDC heavy ends and found them to be about 65 percent chlorine, including large quantities of highly persistent, bioaccumulative, and toxic substances: 302 ppm PCBs, 0.3 percent HCE, 1.2 percent hexachlorobutadiene (HCBD), and 30.6 percent unidentified compounds.<sup>51</sup> If Dow's analysis is representative of heavy ends in general, then EDC oxychlorination results in the worldwide production of a remarkable 20,000 pounds of PCBs each year, even though these compounds were banned from intentional production some 20 years ago.<sup>52</sup>

The vinyl industry claims that these by-products are “contained” within the production equipment and thereby never released into the environment. But releases and contamination have clearly occurred. In 1993, chemists from the Greenpeace laboratory at the University of Exeter analyzed material from a number of European EDC/VCM manufacturers. Soil and gravel samples taken near a Swedish oxychlorination reactor contained a wide variety of persistent organochlorines in the high ppm range, and HCB and HCBD were present at the remarkable levels of 1.9 and 0.6 percent by weight.<sup>53</sup> The following year, Greenpeace obtained samples of heavy ends from several U.S. EDC/VCM manufacturers and had them analyzed by the Exeter laboratory. In one sample from Borden Chemical, 174 organochlorines were identified, including a wide variety of highly chlorinated substances with a range of chemical structures, many of them highly persistent, bioaccumulative, and toxic.<sup>54</sup>

### Dioxin and furan formation

With PCBs and HCB in the wastes from PVC production, it is no surprise that the structurally related and extremely hazardous dioxins and furans are found in significant quantities, as well. Dioxins have been detected in the wastes from VCM synthesis. In research at a chemical plant in Russia, substantial quantities of dioxins and furans were identi-

EDC oxychlorination results in the worldwide production of a remarkable 20,000 pounds of PCBs each year, even though these compounds were banned from intentional production some 20 years ago.



The formation of dioxin in this process is inevitable and unpreventable.

fied in the wastewater and wastewater sludge from the pyrolytic production of VCM from EDC—as well as in the waste incinerator emissions.<sup>55</sup> But the largest quantities of dioxin are formed in the production of EDC by oxychlorination. As the British chemical company ICI made clear in a submission to the government, the formation of dioxin in this process is inevitable and unpreventable:

It has been known since the publication of a paper in 1989 that these oxychlorination reactions generate polychlorinated dibenzodioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs). The reactions include all of the ingredients and conditions necessary to form PCDD/PCDFs, i.e., air or oxygen, a hydrocarbon (ethylene, etc.), chlorine or hydrogen chloride, a copper catalyst, an ideal temperature, and an adequate residence time. It is difficult to see how any of these conditions could be modified so as to prevent PCDD/PCDF formation without seriously impairing the reaction for which the process is designed.<sup>56</sup>

The 1989 paper to which ICI was referring was the work of a group of chemists at the University of Amsterdam who simulated the oxychlorination process in the laboratory and found dioxin formation at a rate that would make this method of producing EDC one of the world's largest—if not the largest—sources of dioxin.<sup>57</sup> These authors estimated that 419 grams of dioxin TEQ are formed per 100,000 tons of EDC produced—a rate equivalent to more than 60,000 grams of dioxin (TEQ) per year from the world vinyl industry.<sup>58</sup> Although not all the dioxins created would be released directly into the environment, this quantity is more than 50 times the annual dioxin emissions from all trash incinerators in the United States—the largest known source of U.S. dioxin emissions. It is also double the 25,000 grams of dioxin (TEQ) per year that EPA estimates are carried into the environment by contaminated pentachlorophenol<sup>59</sup>—the largest identified source of dioxin to any environmental medium.

This research generated considerable public and scientific concern. As a result, the vinyl industry began its own sampling program. In 1993, the Norwegian PVC manufacturer Norsk-Hydro confirmed that its EDC/VCM synthesis plant produced dioxins but claimed the quantities

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were hundreds of times lower than the Dutch study had predicted.<sup>60</sup> How much dioxin is actually formed remains uncertain, because both studies have strengths and weaknesses. On one hand, the Dutch analysis may be a more accurate indicator of total dioxin generation because the researchers captured and analyzed all the material outputs from the oxy-chlorination process. The Norwegian report, like any study of a full-scale facility, inevitably missed some of the by-products, which are directed into too many different equipment surfaces, products, recirculating materials, and wastes to be completely assessed in a large-scale industrial context. On the other hand, the Dutch study was a laboratory simulation, and the industry analysis took place at a real production facility; there may be reasons why the simulation caused more dioxin to form than a real-world synthesis of EDC.

#### **Dioxin releases in wastes**

Whatever the exact quantities, there can be no doubt that dioxin generation occurs in far from negligible amounts. In 1994, government scientists found dioxins at high concentrations (up to 414 ppb TEQ) in sludges from a fully modernized EDC/VCM plant in Germany, refuting the claim that only outdated EDC/VCM technologies produce dioxin.<sup>61</sup> The same year, ICI Chemicals and Polymers found that its vinyl chloride plant in Runcorn, UK, was producing large quantities of dioxin—not as much as the Dutch studies predicted but substantially more than Norsk-Hydro had estimated. Most of the dioxins at ICI were deposited in heavy-end wastes, and smaller quantities were released directly into the air and water.<sup>62</sup>

In the United States, wastes from Vulcan Chemical's EDC plant in Louisiana have been found to contain dioxins and furans at the concentration of 6.4 ppm (TEQ), which makes them among the most dioxin-contaminated wastes ever discovered, on a par with wastes associated with the manufacture of Agent Orange.<sup>63</sup> In 2000, Norwegian scientists reported finding "extremely high" concentrations of dioxins and furans—26.6 ppm (60.7 ppb TEQ)—in the sludges from a VCM/EDC manufacturing plant. Considerable quantities of dioxins and furans had migrated from an on-site disposal facility for these sludges into groundwater, a nearby brook, and the Gulf of Finland in the Baltic Sea. Dioxin and furan levels in several fish



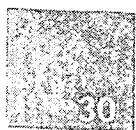
Residents in the Mossville area—located across the road from a large vinyl chloride manufacturing facility—have blood levels of dioxins and furans (TEQ) averaging nearly three times those of a comparison population.

species in the region of the plant were 2 to 9 times higher than levels in fish caught from a relatively uncontaminated local comparison area.

Considerable quantities of PCBs were also found in sediments near the plant and were attributed to the production of EDC/VCM.<sup>64</sup>

The wastes from EDC synthesis have one of two major destinations. In some facilities, wastes are used in the manufacture of chlorinated solvents—wherein the contaminants end up in the wastes or products from those processes. In other facilities, the wastes are disposed of, usually by incineration. (A discussion of environmental releases from this practice follows). But not all by-products of EDC/VCM synthesis end up in the hazardous wastes—some escape directly into the environment. Dioxins have been detected in wastewater discharges and air emissions from a number of EDC/VCM plants,<sup>65</sup> and local and regional contamination of water, sediments, and shellfish has been linked to EDC/VCM manufacturers in Europe and the United States.<sup>66</sup> For example, severe dioxin contamination of sediments in Italy's Venice Lagoon has been linked to an EDC/VCM manufacturing facility.<sup>67</sup> In the Netherlands, levels of dioxins in sediment samples in the River Rhine jump dramatically immediately downstream from an EDC/VCM manufacturing plant.<sup>68</sup> The levels are so high, in fact, that the majority of dioxins in Rhine sediments downstream from the plant—all the way to the river's mouth, and in the entire North and Wadden Seas—appear to be attributable to the facility.<sup>69</sup>

These dioxin releases contribute not only to environmental contamination but also to human exposure. In Lake Charles, Louisiana, the U.S. Centers for Disease Control reported that residents in the Mossville area—located across the road from a large vinyl chloride manufacturing facility—have blood levels of dioxins and furans (TEQ) averaging nearly three times those of a comparison population (an increase that was statistically significant at the 95 percent confidence level). Eggs from chickens raised in the area were found to contain dioxins and furans at levels nearly double those in store-bought eggs; but the sample size was too small for statistical significance to be evaluated. The study did not evaluate specifically whether the increased dioxin levels were due to releases of dioxin from the EDC/VCM synthesis, from on-site incinerators for production wastes, or from some other process at facilities in the area.<sup>70</sup>



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Other by-products are also present near chemical plants that make PVC feedstocks. In Lake Charles, Louisiana, the National Oceanic and Atmospheric Administration (NOAA) found high levels of persistent organochlorines in the water, sediment, and fish of bayous near EDC/VCM facilities owned by PPG and Vista Chemical. According to NOAA, the geographical pattern of contamination indicates that PPG is the primary cause of high levels of organochlorines in the water and sediment. In one portion of the estuary near PPG's facility, concentrations of HCB, HCBd, and HCE exceeded 1,000 ppm in sediment; in some samples, these three by-products represented from 0.1 percent to an extraordinary 4.8 percent of the sediment's total mass.<sup>71</sup>

## POLYMERIZATION, COMPOUNDING, AND MOLDING

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Polymerization of VCM to make pure PVC is a more diffusely structured industry than EDC/VCM synthesis, with smaller quantities of product made at a greater number of facilities. No estimates of the total quantity of VCM released into the workplace and the local environment in these stages are available. Traditionally, worker exposure in this sector has been assumed to be higher than in any other process.<sup>72</sup> As previously discussed, numerous studies of the health of workers in PVC polymerization facilities have been conducted, and they have established a causal connection to angiosarcoma of the liver and revealed statistically significant excesses of brain cancer and neurological effects among VCM-exposed workers. In the United States, worker exposure in this sector has declined in recent decades.

### Occupational health & phthalates

Release of phthalates into the environment and occupational exposure to these substances is another issue in the later manufacturing stages of the vinyl lifecycle. In 1997, chemical and plastics industries in the United States reported releasing 213,621 pounds of the plasticizer diethylhexyl phthalate (DEHP) directly into the air, plus 71,004 pounds into the land.<sup>73</sup> Occupational exposures can be significant: in one plastics molding facility, DEHP levels have been measured at 11,500 nanograms per cubic meter, thousands of times higher than the levels typically found in outdoor air.<sup>74</sup> According to the National Toxicology Program, "workers may

Occupational work with PVC plastic was associated with a 5.6-fold increase in the risk of seminoma—a form of testicular cancer.

be exposed to relatively high concentrations during the compounding of DEHP with PVC resins. The major route of exposure is inhalation."<sup>75</sup>

#### Cancer risk from PVC manufacturing

There are few direct studies of health impacts and phthalate exposure in the PVC manufacturing industry. Two studies by a research group in Sweden indicate an increased risk of testicular cancer among workers in PVC manufacturing industries. In the first study, a variety of occupational exposures were investigated for a possible link to testicular cancer. Work in plastics production was found to cause a 2.9-fold increase in the risk of testicular cancer.<sup>76</sup> The second study tested and clarified the relationship between plastics work and testicular cancer. In this report, using a case-control study of 163 men with testicular cancer and 326 without the condition, occupational work with PVC plastic was associated with a 5.6-fold increase in the risk of seminoma—a form of testicular cancer that occurs later in life and may thus plausibly be caused by occupational exposure. The increased risk was statistically significant and highest among those men with the greatest cumulative exposures. No significant increases in the testicular cancer rate were seen among men who worked with other types of plastics. Because exposure to endocrine-disrupting compounds can lead to testicular cancer, the authors hypothesized that exposure to phthalates used as plasticizers in PVC—some of which are known endocrine disrupters and testicular toxicants—may be the specific cause of the increased risks.<sup>77</sup> These results contrast with those of a Danish study that found no relationship between work in cable manufacture—a large consumer of PVC—and testicular cancer.<sup>78</sup>

#### DISPOSAL OF EDC/VCM WASTES

The organochlorine-rich heavy ends produced by EDC/VCM manufacture are regulated as a hazardous waste in the United States. The majority of these are disposed of by incineration, usually in on-site furnaces at the production facility. In theory, a properly designed and operated incinerator converts organochlorines by oxidation into carbon dioxide, hydrogen chloride, and water. Real-world combustion systems, however, never take this reaction to completion for all the compounds fed into them. Most compounds are completely oxidized, but some fraction escapes unburned.

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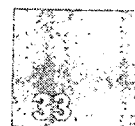
and a larger portion is converted into new organic compounds, called products of incomplete combustion (PICs). According to EPA's technical review document on hazardous waste incineration, "The complete combustion of all hydrocarbons to produce only water and carbon dioxide is theoretical and could occur only under ideal conditions... Real world combustion systems... virtually always produce PICs, some of which have been determined to be highly toxic."<sup>79</sup>

### **Dioxin and other byproduct formation in incinerators**

By-products form in incinerators for the same reasons as in chemical manufacturing: multiple reaction pathways, local optima that lead to stable by-products, and deviations from optimal conditions. In incineration, the problems are particularly acute—wastes are complex mixtures of diverse materials that can never be uniformly blended. Further, combustion is by nature a stochastic process of bond breakage and formation; at high temperatures, most of the molecules will be completely oxidized, but some will follow alternative reaction pathways and emerge as PICs. Transient variations and upsets are a particular problem with incinerators. Good management can reduce but never eliminate the production of PICs, as EPA's analysis made clear:

[Deviations from optimum] usually are a consequence of a rapid perturbation in the incinerator resulting from a rapid transient in feed rate or composition, failure to adequately atomize a liquid fuel, excursions in operating temperature, instances where the combustible mixture fraction is outside the range of good operating practice, or inadequate mixing between the combustibles and the oxidant... The amount and composition of PICs will depend in a complex and unpredictable way on the nature of the perturbation.<sup>80</sup>

The type of incinerator and how well it is operated will affect the magnitude of the PICs released, but the production of chlorinated PICs—including the most hazardous ones like the dioxins and furans—is a universal and inevitable outcome whenever chlorinated wastes are burned. As the British Department of the Environment noted, "Comprehensive tests have established that all waste incinerators, independent of type of incinerator or waste composition, are likely to produce



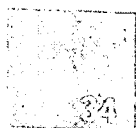
Incinerators not only  
destroy organochlorines,  
they also manufacture  
them.

all of the possible 75 PCDD and 135 PCDF isomers and congeners, as well as about 400 other organic compounds.”<sup>81</sup>

By-products form from diverse and unpredictable reactions not only in the furnace but also in the cooler zones, where control over combustion conditions is nearly irrelevant.<sup>82</sup> Dioxins can even form in pollution control devices or smokestacks, where chlorine gas, hydrochloric acid, or organochlorine precursors come in contact with organic compounds in fly ash. This process, called de novo dioxin formation, is greatly accelerated if iron or copper catalysts are present, as they are in EDC/VCM wastes and municipal trash.<sup>83</sup>

This means that incinerators not only destroy organochlorines, as they are supposed to, but also manufacture them. EPA estimates that PICs formed in the incineration process number in the thousands.<sup>84</sup> Of these, some have been characterized, and the rest remain unidentified. Laboratory tests show that burning methane—the simplest possible hydrocarbon—in the presence of a chlorine source produces more than 100 organochlorine PICs. These by-products, ranging from chlorinated methanes to dioxins, are produced by a set of reactions thought to be common to all incineration processes in which chlorine is present.<sup>85</sup> It is much more challenging to analyze PICs in the stack gas of real-world incinerators, but more than 50 organochlorines or groups of organochlorines have been identified in the emissions of hazardous waste incinerators—ranging from the structurally simple carcinogen carbon tetrachloride to highly persistent and bioaccumulative compounds like chlorinated hexanes, dioxins, ethers, furans, naphthalenes, PCBs, phenols, and thiophenes.<sup>86</sup>

As in other aspects of the vinyl lifecycle, the identified compounds are just the beginning. At hazardous waste incinerators, the most comprehensive research burns have identified about 60 percent of the total mass of unburned hydrocarbons in incinerator stack gases, and most field tests have had far less success in identifying the PICs emitted.<sup>87</sup> There is good reason to be concerned about these mystery compounds because at least some appear to be in the same toxicological family as dioxins. German researchers measuring the dioxin-like toxicity of trash incinerator fly ash



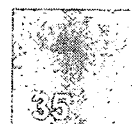
using a biological test found that toxicity was up to five times greater than could be accounted for by the amount of dioxins, furans, and PCBs in the ash.<sup>88</sup> The remaining dioxin-like effect was presumably caused by scores of other compounds—such as chlorinated naphthalenes, diphenyl ethers, thiophenes, and many others—that can cause similar health effects but were not specifically measured.

### Efficient incineration and high emissions

The total quantity of PICs and unburned wastes emitted from incinerators is not known precisely, but it appears to be large. In the United States, hazardous waste incinerators must pass a trial burn that requires them to demonstrate a destruction and removal efficiency (DRE) of 99.99 percent of the organic compounds fed to them, which means that no more than 0.01 percent of several test chemicals fed into the furnace may be measured in stack emissions. But high DREs do not mean that the environment is protected, for several reasons.

- EDC heavy ends are burned in such immense quantities that even if all incinerators achieved 99.99 percent DRE, they would still emit more than 6,600 pounds per year of unburned hazardous wastes into the air in the United States alone.<sup>89</sup>
- Much greater amounts of organochlorines are released as PICs. "Destruction" means only that the chemical tested was transformed into some substance other than the original compound, and PICs are not counted against the 99.99 percent DRE figure. EPA's Science Advisory Board has estimated that the total quantity of PICs that hazardous waste incinerators emit to the air may be up to 1 percent of the organic matter fed to them.<sup>90</sup> This estimate suggests that incineration of heavy ends from vinyl manufacture would emit some 660,000 pounds of PICs each year.
- Still more unburned wastes and PICs are transferred to the land or water where the ash, sludge, and effluent from incinerators are disposed of. These quantities are not included in a DRE, which reflects not only destruction of waste chemicals but also their removal by pollution control

An incinerator burning EDC/VCM manufacturing wastes may be certified as achieving 99.99 percent DRE when, in fact, it is emitting huge quantities of unburned and partially burned wastes.



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devices. An incinerator with a filter that captures 95 percent of the dioxin in the stack gas deposits 20 times more dioxin in its ash than it emits into the air, without any effect on the calculated DRE.

- DREs are calculated from an incinerator's performance when burning test chemicals that are fed in high concentrations, but two EPA studies have found that substances in low concentrations burn much less efficiently. Chemicals that are present in wastes in the ppb or ppm range—such as the dioxins, PCBs, and many other by-products in EDC/VCM wastes—are subject to destruction efficiencies as low as 99 percent, implying that significant amounts of these hazardous substances will escape intact from incinerators.<sup>91</sup>
- DREs measured in trial burns are unlikely to reflect emission rates during routine operation because trial burns involve the combustion of simplified mixtures of pure chemicals under carefully controlled, closely scrutinized conditions. In daily use, incinerators generally perform less efficiently, due to the complexity of real-world wastes and the frequency of upsets, operator error, and equipment malfunction.<sup>92</sup> Further, the standard trial burn protocol allows the measurement of emissions to stop when the feed of waste chemicals to the incinerator stops, but emissions can continue for days, resulting in total emissions of unburned wastes that are orders of magnitude greater—and DREs far lower—than those measured during the trial burn.<sup>93</sup>

For these reasons, an incinerator burning EDC/VCM manufacturing wastes may be certified as achieving 99.99 percent DRE when, in fact, it is emitting huge quantities of unburned and partially burned wastes into the environment.

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## FAILURE OF THE VINYL INSTITUTE'S SELF-CHARACTERIZATION OF DIOXIN RELEASES

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The Vinyl Institute (VI) has argued that its role in dioxin formation is minimal, primarily based on its own study, called the "dioxin self-characterization."<sup>94</sup> In this report, the Vinyl Institute concludes that the U.S. PVC industry releases about 13 grams of dioxin (TEQ) per year to the environment. This estimate is also the basis for the Vinyl Institute's contention that vinyl production is responsible for only a small fraction of identified dioxin releases in the United States.<sup>95</sup>

There are three reasons to be skeptical of the industry's reassurances about its dioxin emissions:

- Even if the Vinyl Institute's estimate is accurate, 13 grams of dioxin per year is still highly significant, justifying action to reduce vinyl consumption. U.S. EPA's current standard for the acceptable daily dioxin intake of an average adult (weighing 70 kg) is 0.153 billionths of a gram per year.<sup>96</sup> Based on its own estimates, then, the vinyl industry's annual releases of dioxin into the environment equal the acceptable annual dose for about 85 billion people. (Not all of the dioxins released by the industry will result in direct human exposures, of course. The point of this calculation is to demonstrate that, because dioxin is so exquisitely toxic, a quantity of dioxin that appears small on a mass basis is in fact extremely significant from a toxicological perspective.)
- The Vinyl Institute's figures on its dioxin releases are likely to be gross underestimates because they omit the majority of the dioxin produced during the vinyl lifecycle. The industry's self characterization analyzed several potential pathways for dioxin release, finding low to moderate quantities of dioxins and furans in samples of EDC, PVC products, air emissions, and wastewater and sludge from its treatment. But numerous pathways that contain the largest amounts of dioxin—along with many PVC-related processes that are major dioxin sources—were completely ignored. No data, for example, were gathered on dioxin contamination of chemical streams that

Pathways that contain the largest amounts of dioxin were completely ignored.



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The Vinyl Institute report did not address what is apparently the largest PVC-related dioxin source—the burning of vinyl in incinerators, smelters, and accidental fires.

re-circulate in the manufacturing process, of light ends and other wastes used in other synthesis processes, and—most importantly, because these are known to be so severely contaminated—heavy ends, tars, and other hazardous wastes that are sent to disposal facilities. Nor did the program address what is apparently the largest PVC-related dioxin source—the burning of vinyl in incinerators, smelters, and accidental fires. Thus, the industry's estimates are grossly incomplete and do not effectively refute the argument that the lifecycle of PVC is a major dioxin source.

- The Vinyl Institute's estimates have not been independently verified. In this self-characterization, the PVC industry decided when and where to take samples, how to collect them, how to analyze dioxin content, which data to present, and how to interpret this data before submitting their results to EPA. While an independent panel reviewed the submission, the industry chose which data the panel saw. Information about the samples—including which facility they came from—was completely confidential, so neither reviewers nor the public had the opportunity to determine whether sampling times and locations accurately represented typical dioxin releases. Most importantly, no one was able to independently evaluate, confirm, or act on the information.

It would be naïve to take at face value the industry's own estimates of the magnitude of its releases of dioxin—a substance that is the subject of major public concern and regulatory activity—particularly when those estimates conflict with a large body of information gathered by independent sources, such as those cited above.

## Notes

1. Leder et al. 1994.
2. Leder et al. 1994.
3. Leder et al. 1994.
4. Leder et al. 1994; see also Thornton 2000.
5. Schmittinger et al. 1986.
6. HSDB 1997.
7. Hutzinger and Fiedler 1988.
8. My calculation of annual loadings assumes world production of 39 million metric tons of chlorine each year (Leder et al. 1994).
9. Polychlorinated dibenzofurans (PCDFs, or furans) are structurally related to 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD, known colloquially as dioxin), the best studied and most hazardous of the dioxin-like compounds, a large group of structurally and toxicologically related group of compounds that includes not only



the furans but also some PCBs, chloronaphthalenes, and many others), together referred to as dioxins or dioxin-like compounds.

10. Rappe et al. 1991.

11. Svensson et al. 1993.

12. Kaminski and Hites 1984.

13. Barrie et al. 1997.

14. Andersson et al. 1993.

15. This research is summarized in Versar, Inc. 1996 and EPA 1998.

16. Environment Agency 1997.

17. Lindqvist et al. 1991.

18. Lindqvist et al. 1991; Pacyna and Munch 1991.

19. Ayres 1997.

20. Chlorine Institute 2000.

21. Burns 2000.

22. The data from Euro-Chlor, presented in Ayres 1997, are the most comprehensive available. The data are based on a mass balance method, so that all mercury consumed is accounted for in one way or another. My calculation of total mercury releases from the chlor-alkali industry uses this range and assumes 39 million tons global chlorine production, 35.5 percent through the mercury process (Leder et al. 1994). The actual total may be higher, since many plants are not likely to be as well operated as those in Europe. Euro-Chlor's estimates of releases to water and air (0.2 and 1.9 grams of mercury per ton of chlorine, respectively) are somewhat lower than estimates made by other parties. One review estimates mercury releases at 3 grams per ton of chlorine for a new chlor-alkali plant, and 10 grams per ton of chlorine for a well-operated existing facility (Schmittinger et al. 1986). Real-world plants in Germany have been found to release 19 grams per ton (SRI International 1993).

23. ATSDR 1998.

24. Harada 1995; Davies 1991.

25. Hill and Holman 1989.

26. National Academy of Sciences 2000.

27. Airey and Jones 1970; Johnston et al. 1993.

28. Maserti and Ferrara 1991.

29. Panda et al. 1990.

30. Energy requirements vary somewhat among the chlor-alkali cell types: the mercury cell requires 3310-3520 kilowatt-hours per ton of chlorine, the diaphragm 2,830 kilowatt-hours per ton, and the membrane process 2,520 kilowatt-hours per ton. Based on the proportion of each cell type in the world industry, the average energy requirement for the industry overall is slightly under 3,000 kilowatt-hours per ton (SRI International 1993).

31. SRI International 1993.

32. Assuming an average global cost of 4.2 cents per kilowatt-hour for chlor-alkali customers (SRI International 1993).

33. In the United States, 109 nuclear plants generated 673 billion kilowatt-hours of electricity, for an average of about 6 billion kilowatt-hours per plant per year (Energy Information Administration 1996).

34. National Institutes of Health 1998.

35. Production estimates are 29,137 kilotons EDC per year, 18,495 kilotons of VCM per year, and 18,135 kilotons of PVC per year (SRI International 1993).

36. Kielhorn et al. 2000.

37. SFT 1993.

38. ATSDR 1993; ATSDR 1995.

39. Kielhorn et al. 2000.

40. ATSDR 1993; ATSDR 1995.

41. Kielhorn et al. 2000.

42. Kielhorn et al. 2000.

43. Kielhorn et al. 2000.

44. Pitot and Dragari 1991.

45. Bowermaster 1993.

46. Bowermaster 1993.

47. Curry et al. 1996.

48. My calculations assume that about 15 million metric tons per year of EDC produced by oxychlorination (half of world production (SRI International 1993), assuming integrated oxychlorination and direct chlorination process in 1:1 molar ratios). Heavy and light ends are assumed to be produced at the rate of 2 kilograms each per ton, based on the fact that production of 168,796 tons of EDC in Sweden per year results in the generation of 335 and 333 tons per year of heavy and light ends, respectively (TNO Centre for Technology and Policy Studies 1996). This figure is slightly lower than that of Rossberg et al. (1986), who estimate 2.3 and 2.9 kilogram heavy and light ends per ton of VCM produced, respectively. Use of more recent figures for global PVC production rates (Kielhorn et al. 2000) increases this estimate by about 50 percent.

49. Rossberg et al. 1986.

50. The lower estimate is from Papp 1996. The upper estimate is from Rossberg et al. 1986, assuming synthesis of EDC in integrated chlorination/oxychlorination facility plus pyrolysis to VCM, and includes releases to air, water, heavy ends, and light ends, except nitrogen gas vented to the atmosphere and aqueous streams.

51. Dow Chemical 1990.

52. This calculation assumes global production of 32 kilotons of EDC heavy ends per year, as discussed in the section above. Use of more recent figures for global PVC production rates (Kielhorn et al. 2000) would increase this estimate by about 50 percent.

53. Johnston et al. 1993.

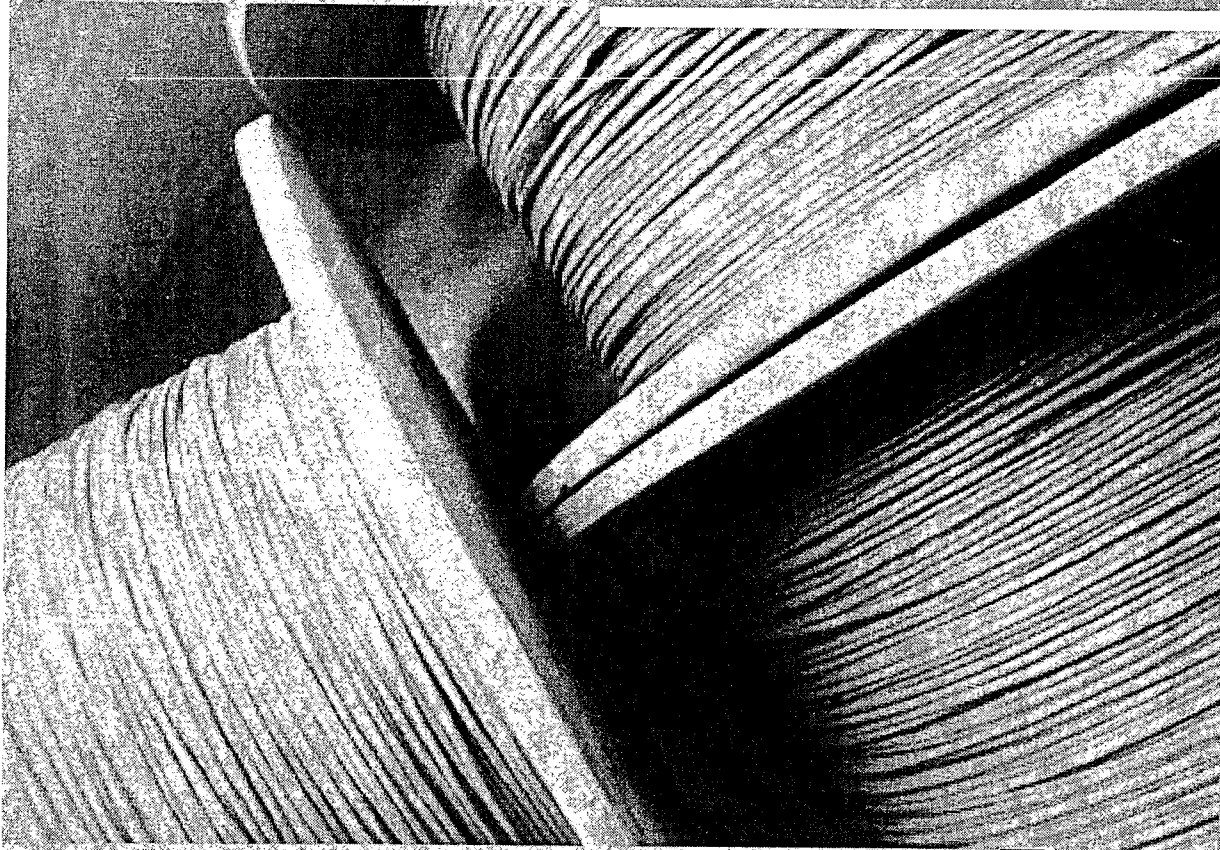
54. Costner et al. 1995.

55. Khizbullina et al. 1998.

56. ICI Chemicals and Polymers 1994.

57. Evers 1989.
58. Based on early 1990s world production of EDC by oxychlorination of about 15 million tons per year (see note above).
59. EPA 1998.
60. The conclusions from this study are summarized in SFT 1993.
61. Lower Saxony Ministry of Environmental Affairs 1994.
62. Total dioxin generation associated with EDC/VCM synthesis was estimated at 27 grams (TEQ) per 200,000 tons of VCM, for a dioxin generation rate of 13.5 grams (TEQ) per 100,000 tons—substantially more than the Norwegian estimate but less than the Dutch figure. If production at the same plant of perc and trichloroethylene from the heavy ends of EDC oxychlorination are included, the estimate of dioxin formation increases to 500 grams TEQ per year from this plant alone. Based on this estimate, all oxychlorination processes would constitute one of the world's largest sources of dioxin (Environment Agency 1997).
63. Costner et al. 1995.
64. Isosaari et al. 2000.
65. DTI 1995; Environment Agency 1997; SFT 1993.
66. Contamination in the UK is described by Environment Agency 1997; in Germany by Lower Saxony Ministry of Environmental Affairs 1994; and in the United States by Curry et al. 1996.
67. Ramacci et al. 1998.
68. Evers et al. 1988.
69. Evers et al. 1993; Evers et al. 1996.
70. U.S. Centers for Disease Control 1999.
71. Curry et al. 1996.
72. National Toxicology Program Center for the Evaluation of Risks to Human Reproduction 2000a.
73. National Toxicology Program Center for the Evaluation of Risks to Human Reproduction 2000a.
74. Rudell et al. forthcoming.
75. National Toxicology Program Center for the Evaluation of Risks to Human Reproduction 2000a.
76. Hardell et al. 1998.
77. Hardell et al. 1997; Ohlson and Hardell 2000.
78. Hansen 2000.
79. EPA 1990.
80. EPA 1989.
81. UKDOE 1989.
82. Dellinger et al. 1988; EPA 1994b.
83. Cullett 1990.
84. EPA 1989.
85. Eklund et al. 1988. Similarly, combustion under well-controlled laboratory conditions of trichloroethylene, another relatively simply organochlorine, produces a variety of persistent organochlorine PICs, including hexachloropentadiene, highly chlorinated benzenes and indenenes, PCBs, and the dioxin-like chlorofulvalenes (Blankenship et al. 1994).
86. Trenholm and Lee 1986; Trenholm and Thurnau 1987; Dellinger et al. 1988; Chang et al. 1988; EPA 1987a and 1987b; Wienecke et al. 1995.
87. EPA 1990.
88. Markus et al. (1997) used a calibrated bioassay to quantify the activity of the cytochrome p4501A1 enzyme, which is induced by dioxin and serves as a "sensitive and selective" marker of dioxin exposure. The total dioxin-like toxicity of the fly ash exceeded that predicted by the quantity of dioxins, furans, and PCBs in the sample by a factor of two to five.
89. Assuming incineration of 30,000 tons of EDC heavy ends per year.
90. EPA SAB 1985.
91. Kramlich et al. 1989; Trenholm et al. 1984.
92. See, for instance, the 1986 analysis by U.S. EPA engineers (Staley et al. 1986), which concluded, "There are several problems with the permitting process [based on trial burns]. First, the trial burn data only indicate how well the incinerator was operating during the time that the data were being taken, typically only a period of a few days. No information is obtained on how the incinerator might respond if fuel, or especially waste, conditions change. Waste streams vary widely in composition and one incinerator may burn many different toxic substances over its useful life, resulting in unavoidable and frequent changes in waste feed conditions. It is difficult to generalize the results of a trial burn to predict how the composition of the incinerator exhaust will change under these varying conditions."
93. Lickis and Mason 1989.
94. Vinyl Institute 1998.
95. Burns 2000.
96. EPA 1985. The "acceptable" dose (0.006 pg/kg of body-weight/day) is the daily exposure that poses a calculated lifetime cancer risk of one per million.

## Use of PVC Products





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## Use of PVC Products

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PVC is not bioavailable, so the polymer itself is not toxic during use. But vinyl products are not pure PVC; they contain both accidental contaminants and chemical modifiers that are added to the plastic on purpose, and some of these may pose health hazards. Moreover, PVC products often encounter reactive conditions—accidental fires in particular—that can transform the plastic into hazardous by-products.

### BY-PRODUCT FORMATION

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Some portion of the diverse organochlorine by-products created in the synthesis of EDC/VCM end up in the PVC itself. In May 1994, the Swedish Environmental Protection Agency found that pure PVC plastic from two Swedish producers contained dioxins, furans, and PCBs at concentrations ranging from 0.86 to 8.69 ppt TEQ.<sup>1</sup> In 1995, the UK government found dioxins and furans in the same range in PVC food packaging items, including cling film and bottles for oils and beverages.<sup>2</sup> Subsequently, the U.S. Vinyl Institute and the European plastics industries conducted their own studies, both of which identified trace quantities of some dioxin congeners in some samples of PVC plastic.<sup>3</sup> The levels were very low, but any quantity of dioxin in consumer products is a matter of concern.

### INDOOR AIR QUALITY: RELEASE OF TOXICANTS

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Because chemical additives are present in PVC in large amounts, they are particularly problematic. PVC additives include a range of toxic compounds, but the most important of these are the phthalate plasticizers and metallic stabilizers. Phthalates can make up a large portion—up to 60 percent by weight—of the final vinyl product.<sup>4</sup> Flexible PVC—including

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flooring, roofing membranes, and wall coverings—accounts for more than half of all vinyl demand, while the remainder is rigid, unplasticized materials such as pipes and siding.<sup>5</sup> Stabilizers—including lead, cadmium, organotin, and other compounds—are used to extend the life of PVC products exposed to light, and they are typically present in lower but still significant concentrations. About 5.4 million tons of phthalates and 156 thousand tons of lead are used each year in the worldwide production of PVC.<sup>6</sup> Vinyl accounts for more than 90 percent of the total consumption of phthalates, so the health and environmental impacts of phthalates are overwhelmingly attributable to PVC.<sup>7</sup>

The additives are not chemically bonded to the PVC polymer but are mixed into the plastic during its formulation. Over time, these additives leach out of vinyl products, entering the air, water, or other liquids with which the product comes in contact. When PVC containers and films are used to hold food products, plasticizers migrate out of the plastic and accumulate in foods, especially fatty ones like cheese and meats.<sup>8</sup> The common practice of storing blood and drug formulations in PVC bags causes phthalates to leach into the container's contents, which can result in substantial short-term phthalate exposures for the recipient.<sup>9</sup> Newborn infants receiving a single blood transfusion have been found to have extremely high levels of phthalates in their systems.<sup>10</sup> When exposure is repeated, blood levels of phthalates can be 100 to 1,000 times greater than "background" and can reach levels at which liver damage and birth defects can occur in animals.<sup>11</sup> Phthalates are also released in significant quantities into saliva when small children suck on vinyl toys and teething rings.<sup>12</sup>

### Release of phthalate plasticizers

Of particular relevance to the health and environmental impacts of building materials is the release of phthalates into indoor air from flexible PVC. The plastics industry has argued that most phthalates have low vapor pressures; therefore they are not expected to volatilize much.<sup>13</sup> But this prediction is not borne out by experience: empirical data make clear that phthalates are released in considerable amounts from vinyl products into the indoor atmosphere. For example, DEHP levels in indoor air average 20 to 103 nanograms per cubic meter, compared to 0.3 to 4.0 nanograms per cubic meter in outdoor air.<sup>14</sup> As one review concluded,

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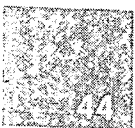


"Phthalates are typically present in indoor air at much higher concentrations than outdoor air due to their high concentrations in consumer products and building materials."<sup>15</sup> According to figures cited by the National Toxicology Program, inhalation accounts for about 15 percent of the average adult's daily intake of DEHP.<sup>16</sup>

The relatively low vapor pressure of most phthalates may explain their tendency to be present on dust particles in higher concentrations than in the vapor phase. One U.S. study of indoor dust and air samples taken from homes and offices found substantial levels of all phthalates tested. Levels were highest of DEHP and butyl benzyl phthalate (BBP), which were present in dust at the remarkably high mean levels of 315 and 117 ppm, respectively.<sup>17</sup> Another recent study of indoor air in Norwegian residences had similar findings, reporting an average of 960 ppm (including 640 ppm of DEHP and 110 ppm of BBP) on sedimented dust particles and 1,180 ppm (more than 0.1 percent) on suspended dust particles.<sup>18</sup> This study also found that a large portion of the phthalate-contaminated dust particles were small enough to be taken into the airway and lungs. As discussed later, phthalates impair reproduction and development, and some are suspected carcinogens.

#### **Phthalate connections to asthma and other conditions**

The high levels of phthalates in indoor air suggest the possibility that these compounds may contribute to the risk of asthma—the cases of which have been steadily increasing in recent decades—particularly among children. In 1997, an analysis of phthalate levels in indoor air pointed out that MEHP—the primary metabolite of DEHP—induces bronchial hyper-reactivity in rats, presumably by its ability to bind to and activate the receptor for prostaglandin D<sub>2</sub>, a locally-acting hormone that triggers inflammation. This report concluded, "We propose that the increase in asthma is due to contributory factors of environmental chemicals in general, and specifically DEHP through its primary hydrolysis product MEHP, which affects the bronchial contracting receptors and thereby generates a hyper reactive condition in the lungs. This will increase the risk of a pathological development in addition to aggravation of the effects of other environmental agents."<sup>19</sup>



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Three epidemiological studies have tested this hypothesis and found evidence that exposure to PVC in building interiors increases the risk of asthma and related conditions. The first study of 251 Norwegian children with bronchial obstruction, with an equal number of healthy children for comparison, found that the presence of PVC flooring in the home was associated with a statistically significant 1.9-fold increase in the risk of bronchial obstruction. Further analysis revealed a dose-response relationship between the amount of PVC and other plasticizer-containing materials in the home and the risk of this condition—a finding that increases confidence that the association between exposure and risk is not a spurious one.<sup>20</sup>

A larger follow-up study in Finland found that children in homes with PVC flooring or wall covering were significantly more likely to suffer from asthma, persistent wheezing, pneumonia, prolonged cough, and phlegm in the airway. The researchers concluded, "Emissions from plastic materials indoors may have adverse effects on the lower respiratory tracts of small children...our findings provide additional evidence that indoor plastic materials may emit chemicals that have adverse effects on the lower respiratory tracts of small children...and warrant further attention to the types of plastic materials used in interior decoration."<sup>21</sup>

A third study focused on the presence of certain breakdown products of DEHP in indoor air. This report by Swedish researchers examined the prevalence of symptoms of eye and nasal irritation, as well as biochemical indicators of inflammation and secretion in these tissues, in relation to the presence of 2-ethyl-1-hexanol (EH) in indoor air. EH is the primary breakdown product of DEHP in damp conditions, which sometimes occur when floors or walls that are covered with an impermeable layer of vinyl become wet. The study examined the staff of four nursing homes—three with PVC flooring, and one without. Workers in the two buildings with damp PVC surfaces were exposed to higher levels of EH and had significantly increased symptoms of nasal and ocular irritation, as well as of biochemical indicators. Other indoor air factors could not explain the finding, as levels of formaldehyde, molds, bacteria, ozone, and NO<sub>2</sub> were low in all four buildings. The authors concluded, "Emissions related to the degradation of DEHP due to dampness in the floors...may affect the

PVC flooring in the home was associated with a statistically significant 1.9-fold increase in the risk of bronchial obstruction.



Vinyl wall coverings are said to be the major cause of mold and mildew in interiors, according to several building industry sources.

mucous membranes in the eyes and nose, decrease tear film stability and increase the occurrence of ocular and nasal symptoms. The low occurrence of both symptoms and signs in the building with special materials and design illustrates that it is possible to construct a new building with a minimum of adverse effects on nasal and ocular membranes."<sup>22</sup>

This evidence does not prove that PVC is a major cause of asthma, but it justifies concern about the role of indoor exposure to phthalate plasticizers in relation to this widespread condition and action to reduce exposures.

### Toxic mold growth

Vinyl's tendency to trap dampness can create another indoor air problem—the growth of toxic molds. Some molds produce toxic and/or allergenic products, particularly among sensitive individuals. These molds do not normally grow indoors but can grow on persistently damp surfaces that contain nutrients (including gypsum and sheetrock), if they are suitably warm and protected from drying out. Repair of the mildewed material has cost millions of dollars, and liability claims are on the rise for property damage and personal injury caused by mold growing inside buildings, including headaches, skin rashes, memory loss, respiratory problems, lung disease, and brain damage.<sup>23</sup> Vinyl wall coverings, because they are impermeable to water vapor, are said to be the major cause of mold and mildew in interiors, according to several building industry sources.<sup>24</sup> The vinyl industry confirms that vinyl wall coverings have created this situation in many buildings; PVC acts as "a vapor barrier that traps moisture inside the wall cavity, where it condenses against the relatively cool inside surface of the wall. Prolonged exposure to these conditions will result in deterioration of the gypsum board."<sup>25</sup> The industry suggests that use of permeable membranes on the outside wall part of the cavity and prevention of moisture infiltration can help reduce the risk of mildew growth.<sup>26</sup> Because dampness and condensation can occur inside vinyl-sealed walls from temperature and humidity differentials produced by heating and air conditioning systems, however, at least one authoritative building industry source recommends avoiding vinyl wall coverings altogether to prevent mold and mildew growth.<sup>27</sup>

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### Releases of lead and other stabilizers

Metal stabilizers are also released from PVC products. Significant releases of lead have been documented from PVC window blinds,<sup>28</sup> leading to a warning by the U.S. Consumer Product Safety Commission. Lead is also known to leach into water carried in PVC pipes that contain lead stabilizers.<sup>29</sup>

But lead continues to be used in building-related materials, as are other hazardous additives. Lead stabilizers are commonly used in pipes, vinyl cables, and window profiles, although their use is greater in Europe than in the United States.<sup>30</sup> Lead accounts for nearly 70 percent of all vinyl stabilizers in Europe, with consumption of more than 51,000 tons of lead in PVC annually, based on 2000 estimates by the European Union.<sup>31</sup> Lead is an infinitely persistent substance and is exquisitely toxic to the developing brain—even in tiny amounts. In November 2000, the Danish government took action to ban the use of virtually all lead compounds, including those in PVC cables, gutters, pipes, roofing, and windows, by no later than 2003.<sup>32</sup>

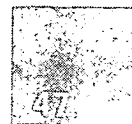
PVC is also associated with other toxic metals. According to the European Commission, 50 tons (110,000 pounds) of cadmium—also a highly neurotoxic and infinitely persistent metal—are used in vinyl each year in Europe, although quantities are declining. Consumption of organotin compounds in vinyl is estimated at 15,000 tons, mostly in rigid films, roofing materials, and clear rigid construction sheeting.<sup>33</sup> Organotins used in vinyl can suppress the immune systems, cause birth defects, damage the liver, bile duct, and pancreas, and may pose hazards to the aquatic organisms when released into the environment.<sup>34</sup> Further, the mono- and di-butyl tin compounds used in PVC are contaminated with tributyl tin (TBT), a potent endocrine-disrupting compound that has caused major damage to marine wildlife populations.<sup>35</sup>

Lead is an infinitely persistent substance and is exquisitely toxic to the developing brain—even in tiny amounts.

### ACCIDENTAL COMBUSTION RELEASES

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The possibility of fire is another major hazard associated with the use of PVC products. Vinyl manufacturers often stress the materials' fire resistant properties—due to the high fraction of chlorine in PVC—as an advantage for hospitals, schools, and other public buildings. In fact, chlorine's resistance to combustion represents a hazard, not a benefit.



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### Hydrochloric gas releases

PVC is now ubiquitous in modern buildings and vehicles. When vinyl burns, the primary combustion products are carbon dioxide, hydrochloric acid, and water. In several major fires, hydrochloric acid has caused severe burns to skin, eyes, and lungs and is an important cause of toxicity to firefighters and persons exposed to fumes and smoke. It can also cause severe damage to computers and other equipment.<sup>36</sup> When large masses of PVC are present—as in vinyl siding or roofing membranes—the hazards may extend to building occupants and the surrounding community.

The hazards of PVC in fires have prompted action or positions by a number of expert organizations. The U.S. military has adopted specifications to avoid PVC-jacketed cables in aircraft, space vehicles, and enclosures in which offgassing may occur in the event of fire.<sup>37</sup> In the United Kingdom, the Fire Brigades Union (FBU) has stated, "The FBU is now particularly concerned about the safety of PVC based building materials that are used in the construction and fitting out of buildings when involved in fire."<sup>38</sup> The International Association of Firefighters has stated,

Because of its majority chlorine content, when PVC burns in fires two hazardous substances are formed which present acute and chronic hazards to fire fighters, building occupants, and the surrounding community. These are hydrogen chloride gas and dioxin. Hydrogen chloride is a corrosive, highly toxic gas that can cause skin burns and when comes into contact with the mucous lining of the respiratory tract creates hydrochloric acid, which can cause severe respiratory damage. Exposure to a single PVC fire can cause permanent respiratory disease.

Dioxin is an unintentional by-product of PVC combustion, and would most likely be left behind in ash and debris from a PVC fire. While only small amounts of dioxin may be formed as the result of burning PVC, it is one of the most toxic substances known to science. Dioxin is a known human carcinogen and has been linked to reproductive disorders, immune suppression, and endometriosis, and other diseases in laboratory animals.




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Due to its intrinsic hazards, we support efforts to identify and use alternative building materials that do not pose as much risk as PVC to firefighters, building occupants or communities.<sup>39</sup>

### Dioxin formation

Accidental fires provide very poor combustion conditions, so substantial amounts of dioxin and other organochlorines form as products of incomplete combustion in a vinyl fire.<sup>40</sup> Indeed, the combustion conditions in an accidental fire, where gases do not mix thoroughly and materials cool rapidly as they escape from the flame, are considered optimal for the rapid production of dioxins.<sup>41</sup> As a result, all accidental fires in buildings containing PVC are likely to generate dioxins and other persistent, bioaccumulative organochlorines. For example, in Germany after a fire in a kindergarten that contained substantial quantities of PVC, scientists measured dioxin levels in indoor soot at concentrations of 45,000 ppt (TEQ)—almost 300 times greater than the German government's health standard. This situation required the building's interior to be completely stripped of PVC—all floors, ceilings, wall coverings, furnishings, and so on—sandblasted, and remediated by hazardous waste experts before children were allowed to enter again.<sup>42</sup> Dioxins have also been identified in the residues from burning automobiles, railway coaches, and subway cars.<sup>43</sup>

Even a small amount of dioxin from each of the 621,000 structural fires and 421,000 vehicle fires in the United States each year could substantially contribute to dioxin contamination of the environment.<sup>44</sup> The German EPA and the German Environment Ministers have called for the use of substitutes for PVC in all areas susceptible to fire, but PVC use in construction continues to grow on a global basis.<sup>45</sup> As a result, a stockpile of PVC, waiting to burn, is accumulating in immense quantities. Worldwide, more than 400 million tons of PVC are "in stock"—that is, in use in various applications, mostly construction-related, and susceptible to fire at some point.<sup>46</sup> The Vinyl Institute has argued that PVC fires are probably a relatively small contributor to the total dioxin burden, based on a study that quantified dioxin levels in soot residues within a limited radius of a fire at a plastics facility.<sup>47</sup> But more than 90 percent of the dioxins produced in a structural fire are in the gaseous phase and escape into the atmosphere,<sup>48</sup> and an additional amount is transported



In Germany after a fire in a kindergarten that contained substantial quantities of PVC, scientists measured dioxin levels in indoor soot at concentrations of 45,000 ppt (TEQ)—almost 300 times greater than the German government's health standard.

beyond the local area, so this study is likely to have underestimated total dioxin emissions by at least a factor of ten. EPA has concluded that the data are currently inadequate to make a firm quantitative estimate of the contribution of accidental structural fires to national dioxin emissions.<sup>49</sup>

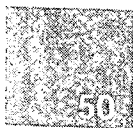
While many small fires taken together may constitute an important source of organochlorines, a single fire at a large commercial building, disposal site, PVC factory, or warehouse can generate large quantities of pollutants. A home contains at most a few hundred kilograms of PVC,<sup>50</sup> but a large building may contain much more. For example, a vinyl-lined roof on an average-sized school contains more than 10 tons of PVC,<sup>51</sup> and a plastics warehouse or landfill may have hundreds of tons on-site. After a fire at a plastics warehouse in Binghamton, New York, dioxin levels in soil on the site were found to be more than 100 times greater than other samples from the same community.<sup>52</sup> Elevated dioxin levels have also been reported in a university building after an interior fire in a lecture hall that contained PVC components.<sup>53</sup> According to the European Commission, fires are estimated to account for 6.6 percent of all dioxin emissions from identified sources (table 4).

### Lead and phthalate releases

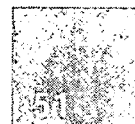
PVC fires not only create dioxins and other organochlorines, they also release additives held in the plastic. The world stock of PVC in use contains a staggering 3.2 million tons of lead and 83 million tons of phthalates.<sup>54</sup> Since lead cannot be destroyed by combustion, accidental fires represent an important potential source of lead exposure—a hazard that looms larger as more and more PVC accumulates worldwide in building applications.

### Notes

1. SEPA 1994.
2. MAFF 1995.
3. Wagenaar et al. 1996; Carroll et al. 1996.
4. DTI 1995.
5. These figures are for Western Europe (European Commission 2000); in the U.S., where unplasticized vinyl siding is more widely used, the relevant figure may be slightly lower.
6. My calculations are extrapolated from the figures for Sweden, where the lead input into PVC equals 0.653 percent of total PVC production, and the phthalate input equals 22.6 percent (TNO Centre for Technology and Policy Studies 1996), assuming 24 million tons of PVC production worldwide.
7. TNO Centre for Technology and Policy Studies 1996.
8. DTI 1995.
9. Pearson and Trissel 1993; Goldspiel 1994.



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10. Plonait et al. 1993.
  11. Dine et al. 2000; National Toxicology Program Center for the Evaluation of Risks to Human Reproduction 2000a.
  12. National Toxicology Program Center for the Evaluation of Risks to Human Reproduction 2000a and 2000c.
  13. American Chemistry Council 2000.
  14. Rudell 2000.
  15. Rudell 2000.
  16. National Toxicology Program Center for the Evaluation of Risks to Human Reproduction 2000a.
  17. Rudell et al. forthcoming.
  18. Oie et al. 1997.
  19. Oie et al. 1997.
  20. Jaakola et al. 1999.
  21. Jaakola et al. 2000.
  22. Wieslander et al. 1999.
  23. Hsieh 2000.
  24. Istiburek and Carmody 1994; Downs 2001.
  25. Vinyl Institute 2000.
  26. Vinyl Institute 2000.
  27. Istiburek and Carmody 1994.
  28. Chicago Tribune 1996.
  29. DTI 1995.
  30. European Commission 2000.
  31. European Commission 2000.
  32. ENDS 2000.
  33. European Commission 2000.
  34. European Commission 2000; Ema et al 1996; Merkord et al 2000; De Santiago and Aguilar-Santelises 1989.
  35. Kemi 2000.
  36. Markowitz et al. 1989; Markowitz 1989; Wallace 1990.
  37. U.S. Navy 1986.
  38. Cameron 1996.
  39. Duffy 1998.
  40. Wirts et al. 1998; Christman 1989; Theisen et al. 1989.
  41. TNO Centre for Technology and Policy Studies 1996.
  42. Fiedler et al. 1993.
  43. Versar, Inc. 1996.
  44. Versar, Inc. 1996.
  45. UBA 1992; German Environment Ministers 1992.
  46. I have extrapolated from figures for Sweden (TNO Centre for Technology and Policy Studies 1996), which indicate that the stock of PVC in use (2 million tons) equals 22.47 years of current PVC production. I have assumed a similar stock-to-production ratio worldwide, and annual PVC production of 19.1 million tons per year (DTI 1995). Use of more recent figures for global PVC production would increase this estimate substantially (Kielhorn et al. 2000).
  47. Carroll 1995.
  48. Versar 1996; EPA 1998.
  49. EPA 1998.
  50. Carroll 1995.
  51. Assuming a roof size of 80,000 square feet and a mass of 0.31 pounds of vinyl roofing membrane per square foot (Cumplings 2001).
  52. Schecter and Kessler 1996.
  53. Deutsch and Goldfarb 1988.
  54. I have extrapolated from figures for Sweden (TNO Centre for Technology and Policy Studies 1996), which indicate that the stock of PVC in use (2 million tons) equals 22.47 years of current PVC production, which contains 15,000 tons of lead 288 thousand tons of phthalates. I have assumed a similar stock-to-production ratio worldwide, and annual PVC production of 19.1 million tons per year (DTI 1995). Use of more recent figures for global PVC production rates (Kielhorn et al. 2000) would increase this estimate by about 50 percent.



## Disposal of PVC Products



## Disposal of PVC Products

The final stage of PVC's lifecycle creates the most severe environmental hazards. About 30 to 50 percent of the vinyl produced annually—some 8 to 12 million tons per year worldwide—ends up in the trash stream.<sup>1</sup> EPA has estimated that at least 1.5 million tons of PVC are disposed of annually in the United States.<sup>2</sup> Although some building materials have a relatively long lifetime, significant quantities of vinyl are disposed of as cutaways in preconsumer waste and, ultimately, in demolition or renovation wastes when a product's useful lifetime ends. Construction products are often thought of as a long-life sector of PVC use, but vinyl products in commercial interiors—often renovated well before their components are physically spent—have relatively short lifetimes.

### THE FAILURE OF RECYCLING

One thing is true everywhere: very little postconsumer PVC is recycled. A substantial portion of preconsumer PVC—scraps and cuttings from manufacturing stages—is recycled, but the quantities of preconsumer waste represent a small amount of the PVC waste stream. Recycling postconsumer PVC is extremely difficult because vinyl products are mixtures of PVC and additives, and each specific formulation is uniquely suited to its application. In virtually all post-consumer vinyl recycling, many formulations are mixed together, destroying the special properties of each. As a result, recycled post-consumer PVC is always of lower quality than the original material, so it can be used only in products without strict material requirements, such as fence posts and speed bumps.<sup>3</sup>

Since recycled PVC is almost never used to make a new version of the original product, down-cycling is a better term for the process than recycling.<sup>4</sup> An example of true recycling is the reprocessing of paper: the old fibers are used to make new paper products, and a new tree does not need



to be cut down. In contrast, a new vinyl wall covering or floor tile must be made of new plastic. Down-cycling does not reduce the amount of PVC produced each year or the total quantity of PVC building up on the planet. The illusion of recycling actually increases the global PVC burden by finding new uses for old PVC while creating a positive image for a product that can be neither safely disposed of nor truly recycled. As the European Commission put it, while true recycling has obvious environmental benefits, "the environmental advantages of the down-cycling of mixed plastics for the production of products which substitute concrete, wood, or other non-plastic applications are less certain."<sup>5</sup>

In the European Union countries, less than 3 percent of postconsumer PVC waste is recycled—the majority of which is actually down-cycling of cable and packaging wastes. According to a 2000 report by the European Commission, "high-quality mechanical recycling for post-consumer [vinyl] wastes is still in a preliminary stage and exists only for a few product groups and with low quantities."<sup>6</sup> Sweden, a nation with an ambitious and effecting recycling program, had a total PVC recycling rate of just 2 percent in 1999, nearly all of it preconsumer waste.<sup>7</sup> The European Commission projects that only 9 percent of all PVC waste is likely to be recycled by 2020, with a maximum potential of no more than 18 percent.<sup>8</sup> Such low recycling rates, even with time to develop an ambitious program, indicate that PVC is not and cannot be a green building material.

The American Association of Postconsumer Plastics Recyclers announced in 1998 that its attempts to recycle PVC had failed and that it would henceforth view vinyl products as unrecyclable contaminants in the municipal waste stream.<sup>9</sup>

There are also concerns about the potential environmental hazards of PVC recycling. Mechanical recycling of PVC can release additives, including phthalates and stabilizers, which may then be dispersed into the recycled products, into the environment, or, if they are captured, disposed of on land or in incinerators. The European Commission has recognized significant concerns about the presence of lead and cadmium stabilizers in PVC products that are recycled and their subsequent dispersal into a greater range of consumer products.<sup>10</sup>

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## LAND DISPOSAL LEACHATES AND FIRES

A significant portion of discarded PVC ends up in landfills, and almost all the remainder is burned—the exact proportions vary from one country to another. In landfills, there are three concerns about PVC disposal. First, the persistence of PVC, which typically lasts for centuries in a landfill, presents a significant burden in terms of the demand for landfill space. Second, the release of additives in the plastic can contaminate groundwater. Because phthalates and metals are not chemically bonded to the polymer, they can leach out of disposed products into landfill leachate, eventually contaminating groundwater.<sup>11</sup>

Third, fires can occur during or after the disposal process, releasing hazardous substances into the air, including dioxins and metals. In Hamilton, Ontario, for example, after some 200 tons of PVC burned at a plastics recycling facility, samples of ash, soot, and tree leaves from the fire area were found to contain elevated quantities of dioxins.<sup>12</sup> Of particular concern are landfill fires, which occur with some regularity at landfills and waste storage sites where large quantities of PVC are present. Data on dioxin releases from landfill fires are limited, but EPA estimates that landfill fires may emit on the order of 1,000 grams of dioxins and furans (TEQ) into the air each year in the United States, potentially making them the largest U.S. dioxin sources to the air.<sup>13</sup>

## INCINERATION

### Role of PVC in incineration

*Dioxin releases:* In every inventory of dioxin sources in the world, trash incinerators and other combustion sources account for the majority of identified dioxin releases into the environment (table 4), and PVC is the predominant source of dioxin-generating chlorine in these facilities. In municipal waste incinerators, PVC contributes at least 80 percent of the organically-bound chlorine and 50 to 67 percent of the total chlorine (organochlorines plus inorganic chloride) in the waste stream—although it makes up only about 0.5 percent of the trash stream by weight.<sup>14</sup> In the United States, an estimated 200,000 to 300,000 tons of PVC is inciner-

Table 4. Inventoried dioxin sources in North America, Europe, and the world.  
Percent of all releases from inventoried sources.

Source type	United States <sup>1</sup>	European Union <sup>2</sup>	United States <sup>3</sup>	Great Lakes <sup>4</sup>	World <sup>5</sup>
* Municipal waste incinerators	40.1	25.1	51.4	20.1	37.6
Ferrous metals production	NA	21.1	0.8	10.6	11.7
* Copper smelting	19.7	1.3	2.6	4.1	2.6
* Medical waste incinerators	17.4	14.2	10.3	48.7	2.8
Forest, brush, straw fires	7.6	NA	7.7	0	11.7
* Accidental fires	NA	6.6	3.7	NA	NA
Wood and coal combustion	6.0	17.1	5.9	4.4	NA
Hazardous waste incineration	5.7	0.6	2.6	8.0	22.7
Dioxin-contaminated chemicals	NA	6.6	4.7	NA	NA
* Uncontrolled trash incineration	NA	3.0	NA	NA	NA
Automobile fuels	1.4	1.9	0.4	1.4	0.4
Cement kilns (no hazardous waste)	0.6	0.4	NA	2.0	10.7

\* Dioxin sources in which PVC is a major chlorine donor.

NA = quantitative estimate not available.

1. Percent of all identified releases to air of PCDD/F (TEQ) based on median estimates for year 1995. Hazardous waste incineration estimate includes releases from cement kilns that burn hazardous wastes, as well as boilers and industrial furnaces.

2. Percent of all identified releases to air in the European Union.

3. Percent of identified emissions of total PCDD/F to the air in the United States as of 1989. Municipal waste incinerators include apartment incinerators. Accidental fires include structural fires, PCB fires, and PCP fires.

4. Percent of identified emissions of PCDD/F (TEQ) to the air that reach the Great Lakes.

5. Percent of identified PCDD/F releases (TEQ) to the air. Estimate for hazardous waste incineration includes cement kilns burning hazardous waste; estimate for cement kilns does not. Estimate for forest, brush, straw fires includes all biomass combustion, including wood.

Source: U.S. EPA 1998; Hanberg et al. 1999; Thomas and Spiro 1995; Cohen et al. 1995; Bizuzy and Hites 1996a.

Note: There are numerous additional dioxin sources for which none of the inventories made a quantitative estimate, due to inadequate data. Sources are listed from largest to smallest, by the percent contribution in EPA's inventory, except for sources with NA in that column, which were ordered according to their contribution in the EU inventory. Sources with less than 1 percent contribution in all inventories are not shown.

ated in trash burners every year.<sup>15</sup> Large quantities of PVC also go to medical waste incinerators, where PVC accounts for 5 to 18 percent of the waste stream—more than 90 percent of the organic chlorine, and more than 80 percent of the total chlorine content of medical waste.<sup>16</sup> As table 4 shows, combustion sources in which PVC is a major source of chlorine—and therefore of dioxin formation—make up the bulk of the world's major dioxin sources identified to date. In fact, sources in which PVC is the dominant chlorine donor account for 77 percent of all inventoried dioxin emissions in the U.S. and 50 percent in Europe.

*Unidentified PICs.* Without a doubt, burning vinyl is a source of dioxin. Numerous laboratory combustion tests involving pure PVC (or pure PVC in the presence of metal catalysts) produce considerable amounts of

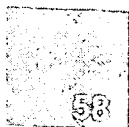
In municipal waste incinerators, PVC contributes at least 80 percent of the organically-bound chlorine in the waste stream.

dioxin.<sup>17</sup> No one has attempted to identify the full range of by-products that form when PVC burns, but 45 organochlorines—including persistent and toxic chlorinated benzenes, naphthalenes, PCBs, PCDFs, phenols, and styrenes—have been found in the combustion products when the closely related plastic polyvinylidene chloride (PVDC; commonly known as Saran Wrap) is incinerated.<sup>18</sup>

As in many other processes, the identified compounds are just the beginning. In municipal incinerators, the most thorough analysis to date identified several hundred PICs, including 38 organochlorines—chlorinated benzenes, ethylenes, methanes, PCBs, and others—but 58 percent of the total mass of PICs remained unidentified.<sup>19</sup> As noted above, a considerable portion of these mystery compounds are likely to be hazardous, and at least some are known to cause dioxin-like toxicity.

*Lead and other additives:* Incinerators also release additives contained in PVC products into the environment. An estimated 45,000 tons of lead stabilizers in PVC enter the world's municipal trash each year, based on Swedish figures.<sup>20</sup> Because lead cannot be destroyed by incineration, all lead that enters an incinerator ultimately enters the environment via stack emissions, ash, scrubber effluent, or wastewater sludges. Incinerators are now the largest source of lead emissions into the environment; PVC is responsible for about 20 percent of the lead in the waste stream, according to Swedish figures.<sup>21</sup> In the European Union, vinyl contributes from 1 to 28 percent of the lead and 10 percent of the cadmium entering municipal waste incinerators.<sup>22</sup>

*Backyard burning:* Not all vinyl burning takes place in high-tech incinerators. In developing countries and rural areas of industrial nations, open burning of waste is a common method to rid trash and debris. A recent study by U.S. EPA and the New York Department of Environmental Conservation indicates that backyard burning of trash in barrels can result in massive emissions of toxic chemicals, including chlorinated benzenes, methanes, phenols, as well as dioxins and furans. Emissions of dioxins and furans per pound of waste burned were 12,000 to 75,000 times higher than emissions from an optimally operated modern trash incinerator.<sup>23</sup> Further, when more PVC was burned, average releases of



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dioxin and all other chlorinated PICs rose substantially; the experiment did not include enough replications for the statistical significance of the increase to be evaluated. Although it is unlikely that construction or demolition waste from commercial buildings will be disposed of by uncontrolled burning, materials used in residential construction in rural areas and developing countries may be. The rapidly expanding use of vinyl in developing nations, where expensive means of waste management are not available, has the potential to cause a major increase in worldwide emissions of dioxins.

*Smelter releases:* Some spent metal products that contain vinyl—including materials used in buildings such as cables and electronics equipment—are recycled or reprocessed in smelters, and these facilities are also major dioxin sources. Secondary copper smelters, for example, recover copper from PVC-coated wire and cable and PVC-containing telephone cases. High dioxin emissions have been measured at these facilities, which are considered major dioxin sources in most inventories.<sup>24</sup> Most importantly, removing some of the vinyl sheathing before cables are fed to the smelters reduces dioxin emissions considerably.<sup>25</sup> Secondary steel smelters have also been found to emit large quantities of dioxin, in part because they recover metal from scrap automobiles that contain PVC.<sup>26</sup> Secondary lead smelters release dioxin and other organochlorines, too, due to the feed of lead automobile batteries with internal PVC parts. In the United States, however, PVC has been recently phased out of this application, so EPA no longer considers lead smelters an important dioxin source.<sup>27</sup>

## **Dioxin formation and PVC—**

### **evidence from combustion experiments**

Following an aggressive effort by the chemical and plastics industry, an apparent controversy has developed over whether burning PVC in incinerators results in increased dioxin emissions. The data, however, strongly support the view that dioxin forms when PVC and other organochlorines burn, and further that burning more PVC (or other organochlorines) results in the formation of more dioxin. This is not to say that the organochlorine content of the waste is the only factor involved in dioxin formation; facility design, operating conditions, and the presence of catalysts also play major roles. Chlorine is a requirement for dioxin synthesis,

Chlorine is a requirement for dioxin synthesis, and preventing the introduction of organochlorines into incinerators is the best means to prevent dioxin formation.

and preventing the introduction of organochlorines into incinerators is the best means to prevent dioxin formation. Conversely, because burning PVC is known to produce dioxin, burning more PVC will produce more dioxin, and burning less PVC will reduce dioxin generation.

Dioxin cannot be formed without a chlorine source, so emissions from incinerators must be the result of burning organochlorines, burning salt, or some combination of the two. To suggest that organochlorines are not important dioxin precursors requires burning organochlorines to produce little or no dioxin and the combustion of inorganic chloride salts to be the predominant source of dioxin. Several lines of evidence indicate that organochlorines—particularly PVC—are the most important and most preventable cause of dioxin emissions from combustors.

The first line of evidence comes from numerous well-conducted studies in the laboratory. Results from the laboratory are particularly convincing because, unlike trial burns at full-scale incinerators, they allow combustion conditions, emissions, and input materials to be carefully controlled and accurately monitored. Studies of this type indicate that burning PVC is clearly an important dioxin source.

- The German EPA has found that burning PVC or other organochlorines produces dioxin—with concentrations in ash residues ranging from 3.2 to 662 ppt (TEQ). But combustion of several types of organochlorine-free but chloride-containing cotton, paper, wood, or wool does not produce dioxin above the detection limit of 0.1 ppt<sup>28</sup> (table 5).
- Two separate studies by Danish researchers have found that burning pure PVC produces dioxin. Under some conditions, the quantities formed are quite large.<sup>29</sup>
- A 2000 report by Japanese researchers found that adding 4 percent PVC to a mixture of chlorine-free materials in a lab-scale incinerator had an “intense effect in dioxin emissions”—a more than 10-fold increase. Adding an equal quantity of salt caused at most a two-fold increase.<sup>30</sup>

Table 5.10: Waste from burning organochlorine and chloride containing materials

Material	Total PCDD/F (ppt)	TEQ
<i>Materials not known to contain organochlorines</i>		
Writing paper	ND	ND
Wood	ND	ND
Cotton	ND	ND
Wool	ND	ND
Polyethylene	2.9	<0.1
Acrylonitrile-butadiene rubber	2	<0.1
Fir wood	21.4	0.65
<i>Organochlorine plastics</i>		
PVC plastic (pure)	244-2,067	3.2-42.2
PVC flooring material	352-1,847	8.2-14.5
PVC window frame material	7.5-969	8.8-18.1
PVC cables (copper)	669-2,670	11.4-52.6
PVC cables (no copper)	416-843	7.4-16.6
PVC gloves, hose, pipes, tape	158-954	2.5-16.5
PVDC plastic	3,304	14.1
Chloropolyethylene plastic	840	10
Polychlorobutadiene (neoprene) plastic	323-1,096	0.7-4.7
<i>Materials containing other organochlorines</i>		
Bleached coffee filters	6.3-7.7	0.15-0.23
Chloroparaffins	1,049	5.3
Dichloromethane	26,302	478
1,1,1-Trichloroethane	21,746	340
Tetrachloroethane	9,072	132
Trichloroethylene	120,915	149.5
Perchloroethylene	212	0.4
Epichlorohydrin	1,532	36
Chlorobenzene	16,135	0.5
p-Chloronitrobenzene	190,096	21.5
o-Chloronitrobenzene	32,293	216
p-Chlorotoluene	1,033	ND
2,4-D	178,016	361
Linuron pesticide	3,110	32

Source: Thelsen 1991.

Numerous well-conducted studies indicate that organochlorines—particularly PVC—are the most important and most preventable cause of dioxin emissions from combustors.

- When newspaper or chlorine-free plastics are burned in a laboratory-scale incinerator, dioxin generation is extremely low. When PVC is added to the mix, dioxin levels in fly ash increase by a factor of 200 to 1,200—compared to a 13- to 45-fold increase when salt is added.<sup>31</sup>
- When PVC is added to a mixture of chloride-containing coal and bark, dioxin concentrations in the residues increase by a factor of 10 to 100; the more PVC added, the higher the dioxin concentration.<sup>32</sup>
- Adding PVC during combustion of natural chloride-containing wood products increases dioxin levels in the ash by 15 to 2,400 times. When large quantities of chemical hardeners containing inorganic chloride are added, dioxin levels rise somewhat, but are still 3 to 350 times lower than when PVC is included in the mix.<sup>33</sup> A Swiss study confirmed these results, finding that dioxin levels in fly ash from the burning of waste wood that has been glued, painted, or otherwise processed are up to 2,000 times higher than in ash from the burning of natural wood.<sup>34</sup>
- Combustion of a mixture of coal and salt produces trace quantities of dioxins and furans in the off-gas, but when elemental chlorine is added to the mix, total dioxin formation increases 130-fold.<sup>35</sup>
- Burning chloride-containing vegetable matter does not produce detectable PCDD/Fs, but including PVC or chlorine gas along with the plant material does.<sup>36</sup>
- The same pattern exists for other organochlorines. Finnish researchers have found that burning perchloroethylene in a laboratory combustion reactor produces more dioxins, chlorobenzenes, and chlorophenols than burning sodium chloride.<sup>37</sup> An American study found that formation of dioxin precursors rises as the proportion of organochlorines in the waste increases,<sup>38</sup> while three others have found that adding salt to a combustion reaction has no detectable effect on dioxin formation.<sup>39</sup>



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In full-scale or pilot-scale incinerators (units smaller than commercial burners but similar in design), the evidence also supports a relationship between burning organochlorines and creating dioxin, but there are also some contradictory studies, possibly due to the difficulty of analyzing complex input and output streams and adjusting for fluctuating operating conditions:

- The Danish EPA has found that doubling the PVC content of an incinerator's waste input increases dioxin emissions by 32 percent, while doubling the chloride content increases dioxin emissions by a much smaller margin.<sup>40</sup>
- A team of Japanese researchers has reported on two separate sets of experiments that showed burning a mixture of PVC and polyethylene—in which PVC is the only chlorine source—produces substantial quantities of dioxin.<sup>41</sup>
- Two groups of researchers from Finland have found that dioxin levels in stack gas or fly ash are very low when a mixture of coal and chlorine-free plastics is burned, but rise substantially when PVC is added to the mix.<sup>42</sup>
- A 1996 study for the Dutch Environment Ministry reported that when both PVC and chloride-containing compostable matter are removed from municipal waste, emissions of chlorophenols—indicator compounds for dioxin formation—were extremely low. When 20 percent of the original amount of compostables was added back into the mix, emissions did not increase, but when 30 percent of the original amount of PVC was added along with the compostables, chlorophenol emissions approximately doubled.<sup>43</sup>
- A series of studies at a pilot-scale incinerator at the University of Florida has documented a clear relationship between the feed of PVC and the emission of chlorophenols. The authors summed up their findings: "These experimental, phenomenological and theoretical studies of toxic emissions from incineration all support the physically intuitive hypothesis that reduction of chlorinated plastics in the input waste stream results in reduction of aromatic chlorinated organic



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emissions.... We are convinced that, when all other factors are held constant, there is a direct correlation between input PVC and output PCDD/PCDF and that it is purposeful to reduce chlorinated plastics inputs to incinerators."<sup>44</sup>

- German scientists have found that removing PVC sheathings from copper cables before they are recycled in copper smelters causes dioxin emissions to drop precipitously.<sup>45</sup>
- Four studies have found that the addition of PVC-containing "refuse-derived fuel" to incinerators burning salt-containing organic matter like wood chips or peat results in significant increases in dioxin formation.<sup>46</sup>
- According to a 2000 study by Japanese researchers, adding PVC to a mixture of chlorine-free matter in a pilot-scale incinerator increases dioxin emissions substantially: when more PVC is added, more dioxin is formed.<sup>47</sup>

In some of these studies, a relationship was seen in the air emissions but not in the fly ash, or vice versa, reinforcing the difficulty of establishing statistically significant relationships in the complex context of burning real wastes in large incinerators.

Two widely cited studies, one by the New York Department of Environmental Conservation<sup>48</sup> and the other by the European plastics industry,<sup>49</sup> have come to the opposite conclusion, finding no relationship of dioxin emissions at individual trash incinerators with PVC content of the waste burned. Neither of these investigations controlled or adjusted for other factors that affect dioxin formation, including facility type, operating conditions, or other characteristics of the waste feed. This oversight radically weakens any study's ability to detect a potential relationship between PVC and dioxin formation. Indeed, an EPA reanalysis of the data from the New York study found that when combustion conditions were adjusted for, emissions of dioxins and furans increased as PVC content of the waste rose.<sup>50</sup>



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A recent Swedish investigation found that dioxin formation is directly related to chlorine content, but only when chlorine levels in the fuel exceed 0.5 percent, as they do in most modern waste streams. Changes in chlorine content below this level had no statistically significant effect on dioxin emissions.<sup>51</sup> These results could indicate that there is a threshold below which chlorine has no impact on dioxin levels, but it is equally possible that the failure to find a correlation at low chlorine levels is an artifact of the limits of chemical and statistical analysis: as levels of both chlorine and dioxin decrease, measurement error and statistical fluctuations become more and more important, swamping a fading signal under a growing chorus of noise.

### **Salt combustion and dioxin formation**

Some studies indicate that burning large quantities of salt can produce dioxin. For instance, paper mills often burn logs that have been soaked in saltwater, and these incinerators have much higher concentrations of dioxin in their emissions than burning unsoaked wood.<sup>52</sup> The Swedish report discussed above found that it did not matter whether the chlorine came in organic or inorganic form—both gave rise to dioxin in approximately equal amounts.<sup>53</sup> One of the Japanese studies also found that burning large quantities of salt in a lab-scale incinerator could result in substantial dioxin emissions.<sup>54</sup> Another study found that burning PVC caused a much greater increase in dioxin formation than salt did, although the two substances caused similar increases in dioxin when municipal incinerator fly ash—which contains a wide range of organochlorines and other compounds—was included in the mix.<sup>55</sup>

These results conflict with the findings of the other studies discussed above, so the importance of salt in dioxin formation in incinerators remains an open question. From a policy perspective, however, it does not really matter how much dioxin salt combustion can produce. If burning chloride results in negligible dioxin emissions, then dioxin output depends almost entirely on the organochlorine content of the waste. Lowering the input of organochlorines is necessary to reduce the formation of dioxin. If, on the other hand, burning salt can produce dioxin in amounts comparable to the burning of PVC and other organochlorines, then dioxin generation depends on the waste's total level of chlorine

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The VI's ASME study is deeply flawed for several reasons—and does not provide an adequate basis to dismiss the many studies that do establish a link between dioxin generation and the combustion of PVC and other organochlorines.

(organic plus inorganic). Lowering the quantity of organochlorines in the waste will then reduce the total chlorine level and reduce dioxin formation. Either way, if we want to prevent dioxin formation in incinerators, we need to stop burning organochlorines.

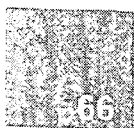
Whatever the quantities, salts are ubiquitous in organic matter and cannot be removed easily from production, commerce, or the waste stream. In contrast, PVC use is highly preventable. Alternatives for most uses are currently available, ranging from traditional materials to chlorine-free polymers.<sup>56</sup> Any program to eliminate dioxin generation at the source should include provisions to reduce the use and combustion of PVC.

#### **Vinyl Institute's flawed ASME dioxin study**

To rebut evidence linking incineration of vinyl to dioxin formation, the Vinyl Institute (VI) frequently cites a single study, purportedly by the American Society of Mechanical Engineers (ASME), a professional society representing 125,000 mechanical engineers worldwide, "[which] found little or no correlation between chlorine input and dioxin emissions from incinerators."<sup>57</sup> This study is deeply flawed for several reasons—and it does not provide an adequate basis to dismiss the many studies that do establish a link between dioxin generation and the combustion of PVC and other organochlorines.

#### *ASME study is biased*

Several vinyl industry documents shed light on the purpose and origins of the ASME report. Just before U.S. EPA released its draft Dioxin Reassessment in 1994, the Vinyl Institute commissioned the public relations firm Nichols-Desenhall Communications to prepare a *Crisis Management Plan for the Dioxin Reassessment*. According to the plan, "EPA will likely conclude that the incineration of chlorinated compounds is the single largest known contributor of dioxin... We believe that PVC will be specifically mentioned and potentially slated for further regulation." In order to "prevent punitive regulation of PVC by EPA, Congress, or the state legislatures," the plan advised the Vinyl Institute how to present itself in the media and "strongly urge[d] VI to aggressively defend the industry's credibility through the use of third party sources to debunk... EPA's misleading claims."<sup>58</sup>



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The industry took the advice of its public relations firm. In 1994, the Vinyl Institute's Incineration Task Force hired the consulting firm Rigo and Rigo, Inc. to prepare an "independent" analysis, which found that the amount of dioxin released by incinerators has no relation to the amount of chlorinated organic materials fed into them.<sup>59</sup> The Vinyl Institute arranged to have the report published as a product of the prestigious ASME, an independent professional organization. According to Vinyl Institute documents, one of the leaders of the Vinyl Institute's Incineration Task Force, Dick Magee, was also an active ASME member; Magee brokered an arrangement in which the Vinyl Institute would hire and fund Rigo to write a report that would be released under the ASME banner. According to an internal Vinyl Institute memo from 1994, the purpose of ASME's involvement was to create the illusion of "third-party" authority, and that the Rigo report was conceived, carried out, and rewarded in a spirit of public relations, not unbiased analysis. The memo reads:

The Vinyl Institute has created an Incineration Task Force in anticipation of adverse EPA actions regarding dioxins and furans... Dick Magee brought forward a proposal from the American Society of Mechanical Engineers to hire Rigo & Rigo Associates, Inc., of Cleveland, OH. The purpose of ASME as the contractor is to provide unassailable objectivity to the study...

The Incineration Task Group interviewed Dr. H. Gregory (Greg) Rigo, principal of Rigo & Rigo Associates, Inc. by phone and found him to be extremely knowledgeable about incineration and to have several proprietary databases VI had not discovered. He is also user friendly, i.e., willing to set his priorities to our needs, and appears to be sympathetic to Plastics, Vinyl, PVC, and Cl<sup>2</sup>...

The ASME proposal calls for \$130,000 for the Rigo & Rigo/ASME study. Since there are many unanswered questions regarding dioxins and since VI may want to use Greg Rigo as an expert witness or advocate to talk about the report, I am proposing an additional \$20,000 as a contingency fund, for a total of \$150,000 to be fully funded by VI.<sup>60</sup>

The study's data and methods on dioxin output and chlorine input were flawed in several ways, suggesting that it's failure to detect a causal link is more likely an artifact of bad study design than a meaningful finding that no relationship between chlorine and dioxin actually exists

#### *Methodological flaws*

The methodology of the Rigo report is no less flawed than its origins, undermining the reliability of its claim that burning organochlorines is not related to dioxin formation. The study was not experimental, so it could not directly refute the existence of a chlorine-dioxin link. Instead of generating new data, the authors compiled existing trial burn measurements from a large number of incinerators, statistically analyzed the relationship between indicators of chlorine feed and dioxin releases, and concluded that there was no statistically significant relationship between the two. A statistical analysis of this type is particularly sensitive to design problems: if the putative cause and effect are not measured accurately, or if confounding factors are not taken into account, then a meaningful relationship is likely to go undetected. In fact, the study's data and methods on dioxin output and chlorine input were flawed in several ways, suggesting that it's failure to detect a causal link is more likely an artifact of bad study design than a meaningful finding that no relationship between chlorine and dioxin actually exists:

1. The Rigo study failed to take account of differences among facilities. Chlorine input is not the only factor that determines the magnitude of dioxin emissions from incinerators; combustion conditions, the types and quantities of substances in the waste, and other variables also affect the amount of dioxin that will be released. Because of this complexity and constant fluctuations of many factors, statistical relationships between stack emissions and indicators of waste input or combustion conditions can seldom be established, even at individual incinerators.<sup>61</sup> Massively compounding this problem, Rigo used data from a large number of incinerators operating under widely variable conditions, but did not control or adjust for differences in facility type, operating parameters, waste type, or other factors. A statistical summary of data from many different facilities, with no attempt to control or adjust for confounding factors, cannot be expected to detect a signal within such extensive noise. Even a strong relationship between organochlorine input and dioxin output is likely to go undetected in a study designed in this manner.
2. The Rigo study also used data from unreliable sources. The emissions data in Rigo's analysis came almost exclusively from trial burns

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designed for permitting purposes, without the proper kinds of controls and measurements necessary to evaluate the relationship between chlorine input and output. Moreover, trial burn data are notoriously problematic. First, with their highly simplified designs, these trials do not accurately represent the way incinerators operate in the real world, when waste composition and operating conditions constantly fluctuate. Further, they do not measure the much larger quantity of chemicals that are released after the feed of waste to the incinerator has stopped.<sup>62</sup> In fact, many trial burns have conducted their evaluations of low- or no-chlorine wastes after chlorinated wastes have been burned, so the later stack samples become contaminated by continuing emissions from earlier runs. The use of results from trial burns of this sort thoroughly scrambles any relationship that might otherwise have been recognizable between chlorine input and dioxin input.

3. Rigo's study relied on the wrong kinds of measurements. To investigate a link between the amounts of organochlorines burned and the amount of dioxin produced by incinerators, Rigo should have examined the statistical relationship between the mass of organochlorines fed to an incinerator and the mass of dioxins released. Instead, the study tracked "surrogate" measures for both of these parameters, measuring the concentration of hydrogen chloride (HCl; the primary by-product of organochlorine combustion) in the stack gas as a rough indicator for the mass of organochlorines in the feed; as a surrogate for the mass of dioxin released, it examined the concentrations of dioxin in the stack gas.<sup>63</sup> The problem is that concentrations do not accurately represent quantities, for several reasons:
- If the total flow of stack gas increases (as it generally will if more waste, and thus more chlorine, is fed to the incinerator), the concentrations of dioxin in the gas may decrease, even if a larger amount of dioxin is being emitted.
  - Stack gas measurements omit pollutants directed into fly ash, bottom ash, and scrubber water, so changes in the efficiency of pollution control devices can reduce the concentration of dioxin in stack emissions while total dioxin formation increases. Control devices can also reduce the concentration of HCl while total organochlorine input

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rises. (Because pollution control devices have different capture efficiencies for dioxin and hydrochloric acid, the concentrations of these materials in the stack gas after it passes through this equipment will not reflect the ratios of the amounts that were actually produced by the incinerator).

- Hydrogen chloride is formed not only by the combustion of organochlorines but also by the burning of chloride salts. It is therefore not a reliable indicator of the amount of organochlorines fed to an incinerator.

The variables that Rigo analyzed are thus grossly inappropriate substitutes for the quantities that are truly of interest; Rigo's failure to find a relationship between the surrogates he used says nothing about whether a link actually exists between organochlorine input and dioxin generation.

All the flaws discussed above cripple the ASME study's ability to establish a link between chlorine and dioxin. A finding of "no relationship" is only as good as a study's power to detect a relationship, and in this case that power can only be described as pathetically weak. On the basis of Rigo's analysis, no reliable inferences can be drawn about whether a relationship exists between the amount of organochlorines burned and the amount of dioxin formed in an incinerator. With more than twenty well-designed studies coming to the opposite conclusion—that burning PVC and other organochlorines produces dioxins, and burning less reduces dioxins—Rigo's findings are far from persuasive. The weight of evidence from laboratory, pilot, and full-scale tests clearly establishes that vinyl is an important source of dioxin in incinerators, fires, and combustion-based recycling facilities, which together are responsible for the majority of identified dioxin releases in the world.

#### **PVC and dioxin relationship—historical evidence**

The theory that burning organochlorines like PVC is an insignificant dioxin source and that salt is responsible for incinerator emissions of dioxin implies several specific predictions, none of which turn out to be true. First, if salt is a more important dioxin source than burning organochlorines, forest fires should result in large dioxin releases because





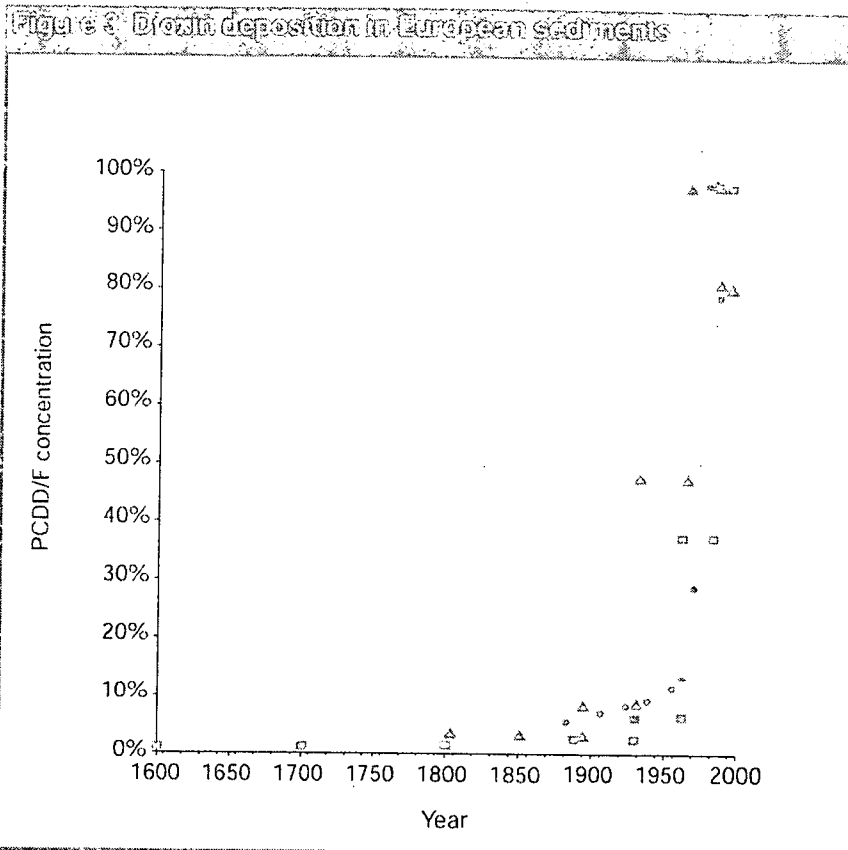
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plant matter is rich in salt. According to research by chemists at Indiana University, however, dioxin levels in the sediment of a U.S. lake, the watershed of which suffered a major forest fire in 1937, show no change whatsoever around or after the time of the fire.<sup>64</sup> More recently, scientists in Spain analyzed samples of salt-containing vegetation and soil that burned in four different 1998 forest fires; the burned materials showed no increase in dioxin levels compared to background levels, leading the researchers to conclude, "Natural fires seem not to be an important source of dioxin-like compounds."<sup>65</sup>

The second prediction implied by industry's salt theory is that historical levels of dioxin should track trends in the burning of salt, not the production and incineration of organochlorines—but they do precisely the reverse. Several studies have analyzed the dioxin and furan content of mummified and frozen remains of people who lived several hundred to several thousand years ago, including individuals from cultures that cooked over indoor fires and were exposed to considerable amounts of combustion emissions. These studies have found that dioxin levels (measured as TCDD-equivalents) in ancient tissues were no more than 1 to 2 percent of the amount found in modern humans, and even this amount could represent contaminants deposited in the samples in modern times, especially during handling and analysis.<sup>66</sup>

Dioxin levels in sediment cores from lakes and seas in North America and Europe also indicate that organochlorines and not the burning of salt are responsible for the bulk of dioxin emissions (figure 3). Every study conducted to date shows that dioxin levels were extremely low before the 20th century when chlorine and organochlorine production began, despite the fact that natural and industrial combustion processes were abundant in this period. Sediments in Swedish lakes show no measurable dioxin before 1945,<sup>67</sup> and those in the Great Lakes show none before 1920.<sup>68</sup> In the Baltic, dioxins and furans were present in a sediment sample dated to 1882, but the levels were 20 times lower than the peak concentrations in 1978.<sup>69</sup> A study of two lakes in Germany's Black Forest found that sediments from the seventeenth and eighteenth centuries contained small quantities of dioxins and furans—77 and 34 times lower than the maximum concentrations from this century. Expressed as

The theory that burning organochlorines like PVC is an insignificant dioxin source and that salt is responsible for incinerator emissions of dioxin implies several specific predictions, none of which turn out to be true.

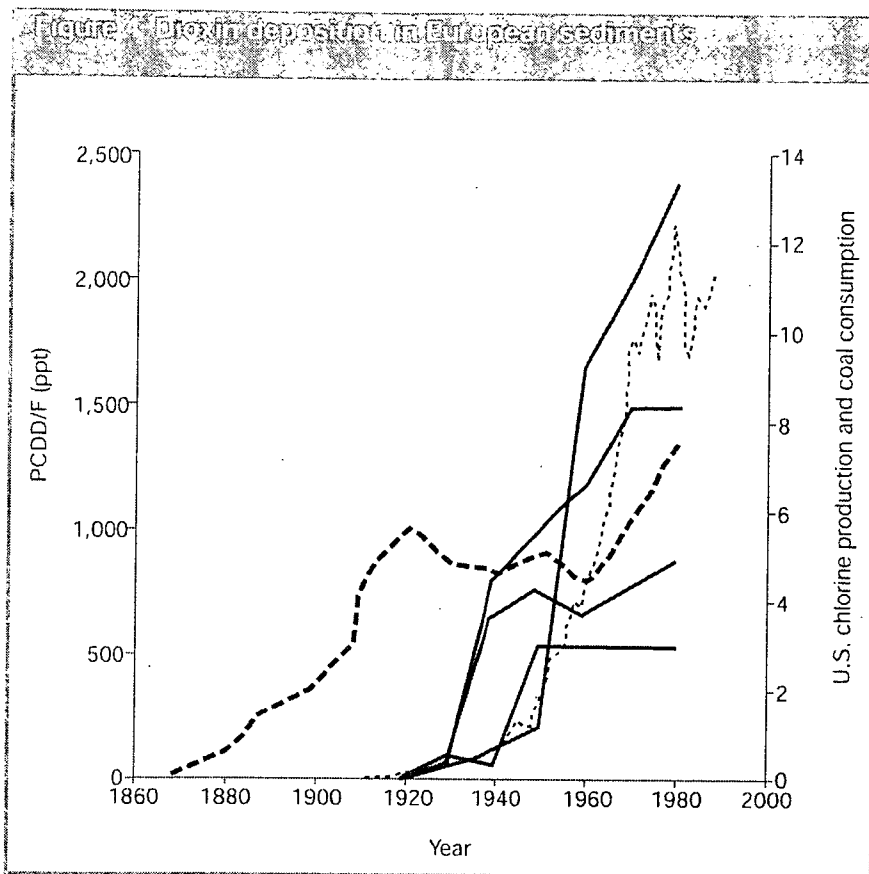


Note: The vertical axis shows concentrations of total dioxins and furans (ppt) in sediment cores from the Baltic (circles) and two German lakes—the Wildsee (triangles) and the Herrenweiser See (squares), expressed as a percentage of the highest levels measured in each location. In all locations, levels were extremely low prior to the advent of chlorine chemistry, and they rise rapidly thereafter.

Source: Juttner et al 1997; Kjeller and Rappe 1995.

TCDD-equivalents, the ratios were even higher: 310 and 90 times greater in modern than in pre-chlorine sediments.<sup>70</sup> In New York's Green Lake, small quantities of dioxins and furans are present in layers from the late 1800s, but at concentrations 1,500 times lower than those found in the 1960s.<sup>71</sup>

Only with the advent of chlorine chemistry and the incineration of its products and by-products did dioxin levels begin to rise. In all samples, dioxin concentrations began to increase slowly in the early decades of this century, then shot up rapidly from the 1940s to the 1970s—rising 25-fold or more between 1935 and 1970, then declining somewhat thereafter.<sup>72</sup> This pattern is consistent with the rise of chlorine chemistry, which peaked in the 1960s



Source: Juttner et al 1997; Kjeller and Rappe 1995.

Every study conducted to date shows that dioxin levels were extremely low before the 20th century when chlorine and organochlorine production began.

or 1970s, followed by restrictions on dioxin-contaminated pesticides and chlorinated gasoline additives went into effect.

Although these trends follow the production of chlorine, they do not even approximately track the history of combustion of salt, either industrial or natural. One study of dioxin trends in Great Lakes sediments found that dioxin levels do not follow trends in combustion of coal—practiced on a massive scale long before dioxin concentrations began to rise—but they do correspond closely to the rise of the chlorine chemical industry (figure 4). These results suggest that industrial combustion processes—including coal-fired power plants, furnaces for heating, rail engines, steel mills, and other industries powered by coal (which contains

Dioxin concentrations began to increase slowly in the early decades of this century, then shot up rapidly from the 1940s to the 1970s consistent with the rise of chlorine chemistry.

chloride salts)—have never been major sources of dioxin. The authors of the Great Lakes studies summarized their results so succinctly that they are worth quoting at length:

There is an abrupt increase in PCDD and PCDF concentrations around 1940... Starting at this time, the production of chlorinated organic compounds such as chlorobenzenes and chlorophenols increased substantially. These compounds are used in a variety of products, including building supplies, herbicides, and packaging. Much of these materials eventually become incorporated in solid wastes. The trend for the production of chloro-organic compounds is similar to the sedimentary PCDD and PCDF profiles. The agreement between these two trends is convincing despite the uncertainties introduced by sediment mixing and the errors inherent in the dating and quantitation techniques... It is clear that the high levels of dioxins and furans found in presently accumulating sediments are not due to the advent of fire.<sup>73</sup>

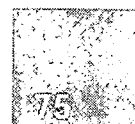
If organochlorines have nothing to do with dioxin emissions, then why were dioxin levels in the environment non-existent or minuscule before the chemical industry began to produce them? In particular, why were dioxin levels so low during the 19th century when combustion of chloride-containing materials such as coal and wood was at its peak? These data make abundantly clear that the majority of dioxin in the environment is due to the production, use, and disposal of chlorine gas and organochlorines.

In conclusion, while it is likely that some dioxin can be formed by the combustion of chloride-containing salts, the available evidence indicates that industrially produced materials containing organochlorines—PVC in particular—are the dominant cause of dioxin generation in incinerators. More importantly, these materials are the most readily preventable cause of dioxin formation. Salts are naturally ubiquitous, but we can choose to stop producing, using, and burning organochlorines. As the Danish Technical Institute has written, "It is most likely that the reduction of the chlorine content of the waste can contribute to the reduction of the dioxin formation, even though the actual mechanism is not fully understood."<sup>74</sup>

PVC is the major chlorine source in the majority of the combustion facilities that dominate inventories of dioxin sources. The production and use of PVC also contributes to dioxin pollution. It therefore appears that PVC is responsible for more dioxin generation than any other single product. As more and more vinyl installed in buildings over the preceding decades enters the waste stream for disposal, the potential for dioxin generation grows accordingly. Any program to eliminate dioxin generation at the source—a public health imperative—should include provisions to reduce the use of PVC in applications susceptible to accidental fire or disposal by combustion.

## Notes

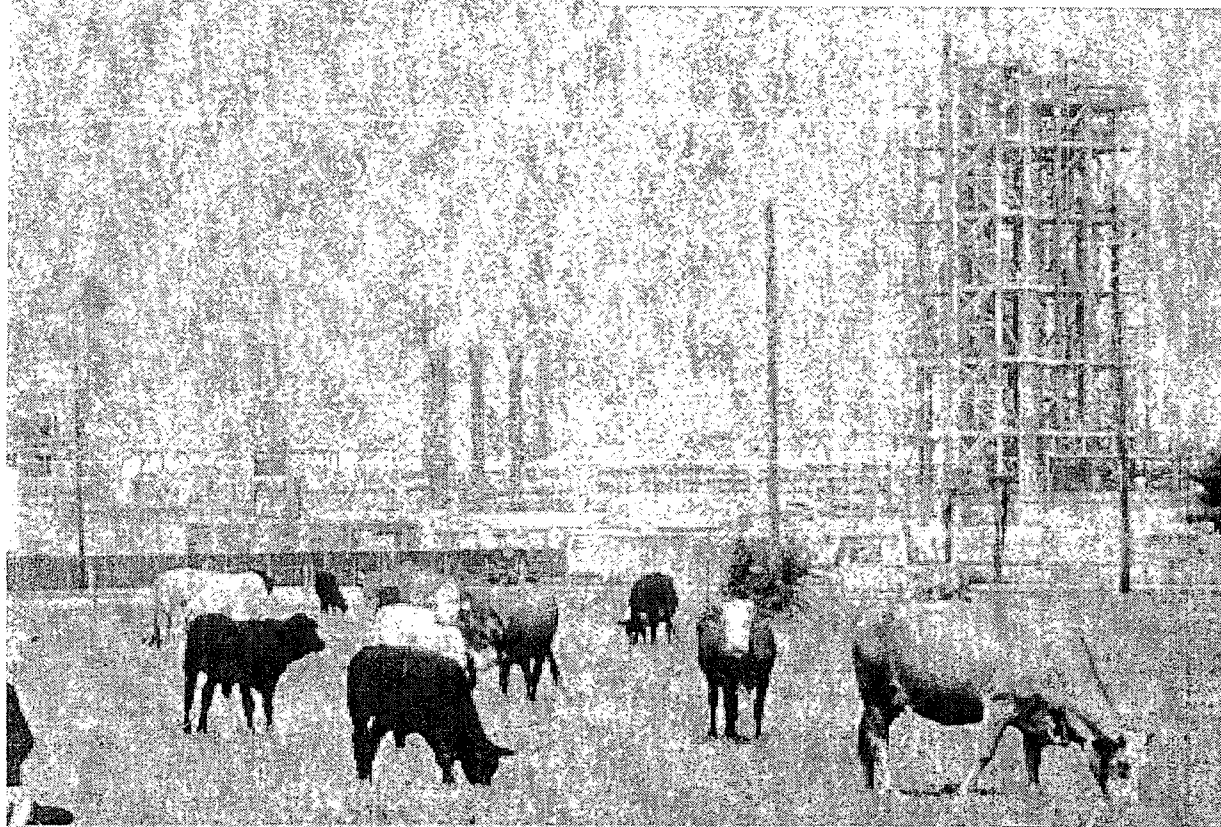
1. TNO Centre for Technology and Policy Studies 1996.
2. Franklin Associates 1997.
3. European Commission 2000.
4. DTI 1995.
5. European Commission 2000.
6. European Commission 2000.
7. Kenil 2000.
8. European Commission 2000.
9. APR 1998.
10. European Commission 2000.
11. European Commission 2000.
12. Hamilton-Wentworth 1997; Socha et al. 1997. Socha et al. notes that dioxin levels in tree leaves downwind from the fire were 7 to 100 times above normal. Apparently, pollutants on the leaves were washed from the leaves into the general environment by rain, because levels on leaves declined significantly after the first post-fire rainstorm.
13. EPA 1998.
14. Danish EPA 1993; Ecocycle Commission of the Government of Sweden 1994; DTI 1995; TNO Institute of Environmental and Energy Technology 1994.
15. This assumes U.S. municipal waste incinerator capacity of 48 million tons per year (Versar 1996), 80 percent capacity utilization, and PVC content of 0.5 to 0.8 percent.
16. According to two studies, 9.4 percent (Marrack 1988) and 15 percent (Hasselriis and Constantine 1993) of infectious red-bag waste in the U.S. is PVC, and as much as 18 percent of non-infectious hospital wastes are PVC (Hasselriis and Constantine 1993). In Denmark, PVC accounts for about 5 percent of all medical waste (DTI 1995). See also Green 1993.
17. Christmann et al. 1989; Theisen et al. 1989; Theisen 1991.
18. Yasuhara and Morita 1988. See also Blankenship et al. 1994.
19. Jay and Stieglitz 1995.
20. I have extrapolated from the relevant figures for Sweden, where 249 tons of PVC enter the waste stream each year (TNO Centre for Technology and Policy Studies 1996), assuming 19.1 million tons of PVC production worldwide, each year (DTI 1995).
21. TNO Centre for Technology and Policy Studies 1996.
22. European Commission 2000.
23. Lernieux 1997. PCDD/F emissions (total) from an avid recycler with high PVC content in their waste averaged 269.6 micrograms per kilogram of waste burned; from a non-recycler with much lower quantities of PVC, and PCDD/Fs averaged 44.30 ug/kg of waste. There were only two runs for each type of trash, so conclusions about the role of PVC in dioxin emissions are tentative. EPA contrasted these high levels of dioxin emissions to those from a municipal waste combustor, which EPA estimated at 0.0035 ug/kg of waste. This figure may be lower than many incinerators in the real world, but the point that uncontrolled burning of waste produces relatively high quantities of dioxin is almost certainly correct. My estimate of the number of households required to produce the same amount of PCDD/Fs assumes, as EPA's report does, an incinerator burning 182,000 kilograms of waste per day, as compared to an average of 4.9 kilograms per day in non-recycling households.
24. Christmann 1989; EPA 1994a; Versar, Inc. 1996.
25. Christmann et al. 1989.
26. Lahi 1994; Schauri et al. 1993; EPA 1994b; Aittola et al. 1993.
27. Versar, Inc. 1996.
28. Theisen 1991.
29. Christman 1989; Vikelsøe and Johansen 2000.
30. Ishibashi et al. 2000.
31. Takasuga et al. 2000. When fly ash from a municipal incinerator was added to the mix, baseline concentrations of dioxin were higher, and, as discussed below, addition of PVC or salt yielded similar increases in dioxin levels.
32. Kopponen et al. 1992.



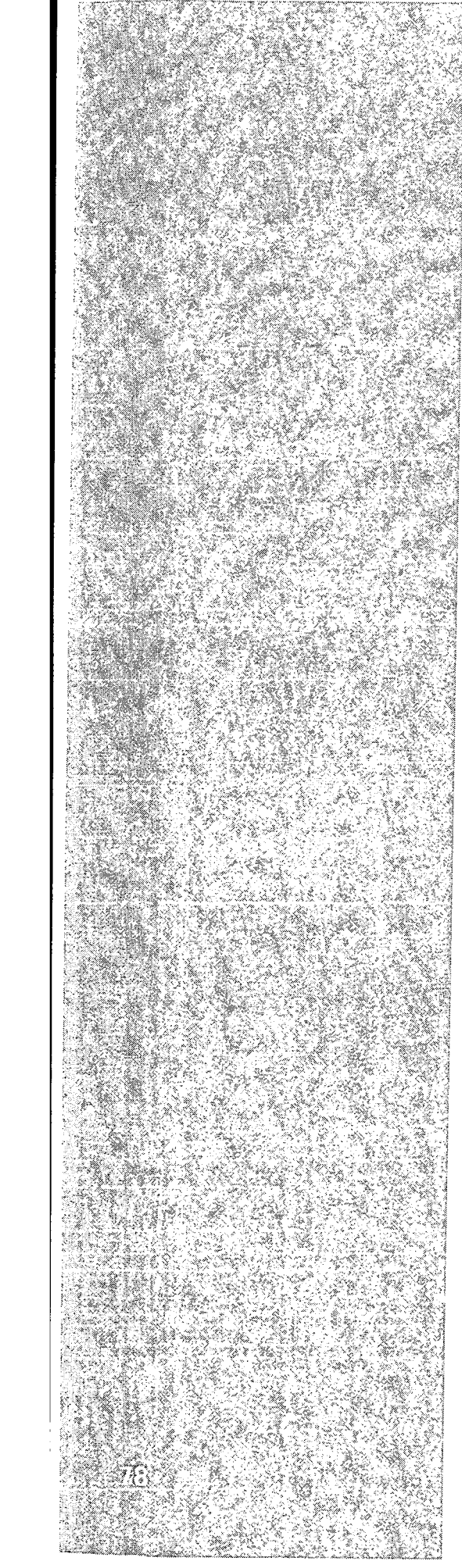
33. Kolerida et al. 1994; Wilken 1994.
34. Wunderli et al. 2000.
35. Mahle and Whiting 1980.
36. Liberti et al. 1983.
37. Halonen et al. 1995.
38. Altwicker et al. 1993. In this study, increasing the feed of organically-bound chlorine results in a substantially higher ratio of chlorophenols to chlorobenzenes in the combustion products; chlorophenols are considered precursors for dioxin formation.
39. Bruce et al. (1991) found that addition of potassium chloride, sodium chloride, or calcium chloride to a combustion reaction had no effect on the quantities of dioxins and furans formed and deposited in the fly ash. Addink et al. (1998) added sodium chloride to fly ash and found that it did not participate in the de novo formation of dioxins and furans. Lenoir et al. (1991) burned sodium chloride with polyethylene in a fluidized bed combustor and found no effect on the amount of dioxins and furans emitted.
40. Danish Environmental Protection Agency 1993.
41. Tamade et al. 2000; Yoneda et al. 2000.
42. Mattila et al. 1992; Ruuskanen et al. 1994; Frankenhauser et al. 1993.
43. This study by Kanters et al. (1996) focused on emissions of chlorophenols as a surrogate for dioxin, due to the difficulty and expense of dioxin sampling and analysis.
44. Wagner and Green 1993; this study also measured emissions of chlorophenols as a dioxin surrogate.
45. Christmann et al. 1989.
46. Vesterinen and Flyktmann 1996; Halonen et al. 1993; Hutoari and Vesterin 1996; Manninen et al. 1996. In all of these studies, dioxin levels in fly gas or flue gas increased with increasing feed of refuse-derived fuel to the burner, which was significantly higher in chlorine content than the organic matter used in comparison runs.
47. Hatanaka et al. 2000.
48. Visalli 1987.
49. Mark 1994.
50. EPA 1988.
51. Wikstrom et al. 1996.
52. Pandrompatam et al. 1997.
53. Wikstrom et al. 1996.
54. The report of Hatanaka et al. (2000) also found that NaCl and PVC resulted in similar increases in dioxin formation, although the unusually high concentration of NaCl added was thought to have resulted in less optimal combustion conditions, possibly increasing dioxin emissions indirectly.
55. Takasuga et al. 2000.
56. Thornton 2000.
57. Burns 2000.
58. Burnett 1994.
59. Rigo et al. 1995.
60. Goodman 1994.
61. Illustrating this point, even carbon dioxide, a widely accepted indicator of combustion conditions, is not consistently related to the emission of unburned wastes, according to Staley et al. 1986 and EPA 1990.
62. Licit and Mason 1989.
63. Rigo analyzed Hydrogen chloride in stack gas for municipal and medical waste incinerators. For hazardous waste incinerators, his analysis was based on the percent chlorine in the waste feed, a parameter that also does not reflect the mass of chlorine. If the percent of chlorine stays the same and total waste feed is increased, then the mass of chlorine feed will increase but would not have been noted using Rigo's approach. Further, increasing the waste feed typically increases the stack gas flow rate, which will tend to reduce dioxin concentrations even if the mass of dioxin emitted increases.
64. Brzuzy and Hites 1996b.
65. Martinez et al. 2000.
66. Schecter 1991; Ligon et al. 1989; Schecter et al. 1988; Tong et al. 1990.
67. Reviewed in Alcock and Jones 1996.
68. Czuczwa and Hites 1986; Czuczwa et al. 1984; Czuczwa and Hites 1985.
69. Kjeller and Rappe 1995.
70. Juntner et al. 1997.
71. Reviewed in Alcock and Jones 1996. Echoing these findings, EPA scientists, in a study of 11 lakes in remote parts of the U.S., found that PCDD/F concentrations in pre-1930 sediments were at most one-tenth the levels in more recent layers (Cleverly et al. 1996).
72. Brzuzy and Hites 1996b.
73. Czuczwa and Hites 1984. Additional data are reported in Czuczwa and Hites 1986 and 1985.
74. DTI 1995.

# Background Persistent Organic Pollutants (POPs)

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## Background on Persistent Organic Pollutants (POPs)

In recent years, there has been extensive scientific and political activity on toxic pollutants, their global distribution, and their effects on highly exposed populations and the general public. An understanding of that context strengthens the case for action to restrict PVC in building applications, and action on PVC would in turn strengthen international efforts to reduce persistent toxic pollution at the source.

### GLOBAL DISTRIBUTION OF POPs

Recently the first global agreement to eliminate sources of persistent organic pollutants (POPs) has been negotiated. The POPs treaty is, in large part, a response to scientific research in the past decade that has identified a variety of synthetic chemical pollutants that are now globally distributed in the environment and food web, have damaged wildlife populations, and may have caused large-scale human health damage.<sup>1</sup> Global contamination has occurred because many synthetic chemicals are persistent in the environment, resisting natural degradation processes for months, years, or even decades. As a result, even substances that are discharged at a relatively slow rate build up to higher levels over time and are distributed widely by air and water. Because many synthetic organic substances are derived from petrochemicals, they are oil soluble and therefore bioaccumulate—they build up in the fatty tissues of living things and multiply in concentration as they move up the food chain. Some bioaccumulative substances reach concentrations tens of millions of times greater than their levels in the ambient environment in species high on the food web, including humans.<sup>2</sup>

Releases of persistent and/or bioaccumulative substances since the expansion of synthetic chemical manufacturing after World War II has resulted in



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the global accumulation of POPs in areas remote from any known sources of these substances, including the high Arctic,<sup>3</sup> the isolated rainforests of South America and Africa,<sup>4</sup> and remote regions of the deep oceans.<sup>5</sup> In the Arctic, where long residence times, cold temperatures, and long food chains combine to enhance the persistence and bioaccumulation of organic chemicals, body burdens of humans and wildlife are as much as an order of magnitude greater than in temperate latitudes of industrialized nations.<sup>6</sup>

Although research and policy have focused primarily on a handful of substances—dioxins, PCBs, and about a dozen organochlorine pesticides—global contamination cannot be reduced to a few “bad actors.” In the Great Lakes, 362 synthetic chemicals have been “unequivocally identified” in the water, sediments, and food chain. The list includes the infamous POPs, but it also contains a full spectrum of less familiar substances, from solvents and chemical intermediates to a host of complex industrial specialty chemicals, by-products, and breakdown products.<sup>7</sup> By-products of chlorinated chemical manufacture and disposal are present in measurable quantities in the Canadian Arctic<sup>8</sup> and over the remote Atlantic Ocean,<sup>9</sup> and a variety of chlorinated benzenes are components of rain and snow.<sup>10</sup> Chlorinated solvents, refrigerants, and their environmental degradation products have become truly ubiquitous contaminants of the atmosphere and vegetation.<sup>11</sup>

With the environment and food web ubiquitously contaminated, it should come as no surprise that people are contaminated as well. Human exposures come through inhalation, drinking water, and eating food. For highly bioaccumulative substances, the vast majority of the average individual's exposure—in excess of 90 percent—comes through the food supply, primarily from animal products.<sup>12</sup> At least 700 xenobiotic organic chemicals are present in the adipose tissues of the general population of the United States.<sup>13</sup> Close to 200 organochlorine by-products, metabolites, pesticides, plastic feedstocks, solvents, and specialty chemicals have been specifically identified in the blood, breath, fat, milk, semen, or urine of the general U.S. and Canadian populations—people with no special workplace or local exposures to these substances. Fat-soluble chemicals that have accumulated in a woman's body easily cross the placenta and are concentrated in breast milk.

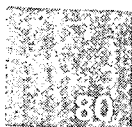
“Acceptable” substances that persist or bioaccumulate cannot be integrated into natural cycles. The ecosystem's assimilative capacity for persistent or bioaccumulative substances is therefore zero, and the only “acceptable” discharge is also zero.

The now-ubiquitous global presence of synthetic chemicals—in large-scale production for just over than half a century—supports a simple inference: substances that persist or bioaccumulate cannot be integrated into natural cycles. Discharged in even small amounts, these chemicals build up gradually in the environment and in living things. Given enough time, even small “acceptable” discharges reach unacceptable levels. The ecosystem’s assimilative capacity for persistent or bioaccumulative substances is therefore zero, and the only “acceptable” discharge is also zero. Any amount greater than zero must be expected to lead to some degree of long-term, large-scale contamination. For this reason, strategies designed to eliminate the materials and processes that produce persistent or bioaccumulative substances are far superior to those that attempt to control, manage, or dispose of persistent chemicals after they have been produced.

## ENDOCRINE DISRUPTION

What are the impacts of universal exposure to POPs on the health of people and wildlife? Important discoveries have emerged in the past decade from toxicology, epidemiology, and ecoepidemiology on the hazards of low-dose exposure. Traditionally, toxicological studies have focused on frank manifestations of toxicity at relatively high doses, such as cancer, organ damage, paralysis and tremors, structural birth defects, and death. Recently, however, it has been discovered that many synthetic chemicals can, at minute doses, result in subtle but significant deficits in an organism’s functional capacities, such as fertility, immunity, cognition and intelligence.

Many of these effects occur as the consequence of a newly recognized set of toxicological mechanisms—disruption of the body’s endocrine system.<sup>14</sup> The endocrine system comprises the hormones, the glands that produce them, and the response of diverse tissues to these substances. Hormones are the body’s natural signaling molecules, circulating in the blood in low concentrations (typically in the ppt range) and triggering cascades of gene expression that control essential aspects of development, behavior, immunity, reproduction, and the maintenance of homeostasis.



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In the past decade, a flurry of research has identified dozens of industrial and agricultural chemicals that disrupt the endocrine system. Some mimic or block the activity of the body's endogenous hormones by interacting directly with the hormone receptor molecules mediating the response of cells to hormones—such as the steroids estrogen, testosterone, progesterone, and the stress hormones cortisol. Others change the rate at which the body produces or excretes its own hormones, causing unnaturally low or high levels of steroid, retinoid, and thyroid hormones. Still others disrupt local signaling mechanisms that are critical to development, brain function, and the immune response, including growth factors, neurotransmitters (molecules that mediate communication among brain cells), and cytokines (intercellular signaling molecules that regulate immune function).

The U.S. National Academy of Sciences has reviewed the evidence on endocrine disruption and concluded that adverse developmental, immunological, neurological, and reproductive effects have occurred in human populations, wildlife, and laboratory animals as a consequence of exposure to hormonally active compounds found in the environment.<sup>15</sup> According to the Academy, effects observed include functional and structural abnormalities of the reproductive tract, reduced fertility, behavioral changes, reduced cognitive ability, and immune suppression. Many studies of wildlife have shown associations between health impacts and exposure to endocrine disrupting substances, including in large ecosystems like the Great Lakes and Baltic Sea with pollutant concentrations that are increased above universal levels by less than an order of magnitude. There is evidence that the health of the general public may have been compromised by universal exposure to these substances, but the Academy did not reach consensus on this point. The panel noted that the degree of support for this hypothesis depends on perspectives that are informed by values, including the standard of proof that should be satisfied before conclusions about public health are drawn, what kinds of effects are worthy of concern, and how scientific findings about effects on one species or stage of life should be extrapolated to others.

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## DIOXIN AND RELATED COMPOUNDS

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### Occurrence and exposure

The most intense scientific activity has focused on 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD, also known colloquially as dioxin) and other structurally similar compounds that act through a similar toxicological mechanism (called, collectively, dioxin-like compounds). Research on dioxins is particularly relevant to the PVC debate because of the evidence that the PVC lifecycle is a major source of dioxins.

A typical nursing infant in the United States receives a daily dioxin dose 92 times greater than that of the average adult.

Dioxins are extremely persistent substances that break down slowly if at all in the environment. Dioxins are also powerfully bioaccumulative and are now globally distributed in the ambient environment and food web. They can be detected in the tissues and fluids of the entire U.S. population. They are cleared from the body extremely slowly: U.S. EPA estimates an average half-life for TCDD in humans of more than 7 years; the body burden of the average adult therefore increases throughout life as the substance gradually accumulates in fatty tissues. Dioxins are passed transgenerationally with great efficiency; a typical nursing infant in the United States receives a daily dioxin dose 92 times greater than that of the average adult.<sup>16</sup>

### Health impacts of dioxin

In 2000, U.S. EPA released its Dioxin Reassessment,<sup>17</sup> a comprehensive scientific summary and analysis of research in dioxin toxicology and epidemiology, and has come to the following conclusions:

- Epidemiological and laboratory studies have established that dioxin is a human carcinogen, echoing the findings of both the U.S. National Toxicology Program and the International Agency for Research on Cancer.<sup>18</sup> *Dioxin is the most potent synthetic carcinogen ever tested*, causing increases in specific cancers and cancers of all sites at extremely low doses. In utero exposures to small quantities of dioxin are associated with increased cancer of hormone-responsive organs (such as mammary glands) when the exposed animal reaches adulthood.

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- *The general public's exposures to dioxin pose a calculated cancer risk in the range of one per 100 to one per 1,000—at least 1,000 times greater than the usual acceptable risk.*<sup>19</sup> People who eat greater than average quantities of meat or fish are subject to even higher cancer risks. (EPA's estimates are based on numerous assumptions and may or may not accurately reflect actual risks.)
  - Dioxin's non-cancer effects may be of even greater concern than its carcinogenicity. *Dioxin is a potent endocrine-disrupting substance*, interacting with an intracellular receptor and disrupting the action of gonadotropins, retinoic acid, steroid hormones, thyroid hormone, and growth factors at extremely low doses. Exposure to even a single tiny dose before birth can lead to profound effects on development of the brain and reproductive system, with effects including impaired cognitive ability and IQ, reduced sperm density, smaller or malformed reproductive organs and structures, and impaired sexual behavior.
  - *Dioxin is a powerful immune suppressant*, interfering with immune function and increasing susceptibility to infectious disease at extremely low doses.
  - *The current body burden of the general human population is already at or near the level at which dioxin has been found to cause a variety of effects in laboratory animals and human populations*, including cognitive defects, endometriosis, hormonal changes, immune suppression, reduced sperm count, and impaired development of the male and female reproductive systems.<sup>20</sup>
  - *There is no evidence of a threshold dose of dioxin below which no adverse health impacts occur.* For all responses that have been studied—including expression of target genes, growth of pre-malignant liver tumors, and changes in circulating levels of thyroid hormones—the best estimate of dose-response relationships at low levels of dioxin is that the severity of the impact is roughly proportional to the magnitude of dioxin exposure.<sup>21</sup>

Doses of TCDD as low as 2.5 parts per quadrillion—equivalent to a mere 10 molecules per cell—completely abolish the ability of cultured immune cells to respond to signals to proliferate and mount an immune defense.

Supporting the view that there is no practical threshold for dioxin toxicity, several studies have discovered that almost infinitesimally low doses have significant biological effects. For example, when rats are given a single dose of TCDD as low as 64 billionths of the animal's body weight on day 15 of pregnancy, the behavior, function, and sexual development of their male offspring are compromised.<sup>22</sup> Dioxin's immunotoxicity has been documented at even lower levels. Doses of TCDD as low as 2.5 parts per quadrillion—equivalent to a mere 10 molecules per cell—completely abolish the ability of cultured immune cells to respond to signals to proliferate and mount an immune defense.<sup>23</sup> In whole animals, dioxin produces immunotoxicity at concentrations in the spleen about five times lower than this—on the order of just two molecules per cell.<sup>24</sup> If there is a threshold for dioxin, it is so low that it is irrelevant for the purposes of environmental policy and health protection.

In addition to these findings, evidence from wildlife suggests a significant current environmental health hazard from dioxin contamination. A large number of ecoepidemiological studies have established that bioaccumulated dioxin-like compounds have caused large-scale epidemics of developmental impairment, endocrine disruption, immune suppression, and reduced fertility in mammals, fish, and birds in the Baltic Sea, the Great Lakes, and the Wadden Sea.<sup>25</sup>

Together, these findings indicate that we cannot assume that the general public has any margin of safety for dioxin exposure. Indeed, it is possible—though not proven—that dioxin-like compounds already contribute to society-wide rates of cancer, endometriosis, immune suppression, impaired cognitive development, and infertility. From a public health perspective, universal dioxin exposure is already too high by a considerable margin. Further releases of dioxins into the environment should be eliminated wherever technically feasible.

### **Trends in dioxin contamination**

Trends in dioxin levels in the environment support the conclusion that measures to reduce dioxin generation through material substitution can effectively reduce contamination and human exposure. Numerous studies of soils and sediment in Europe and North America show that dioxin lev-

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els were very low before the 20th century (figure 3). They began to rise slowly around the turn of the century and then increased rapidly from 1940 to 1970, the period during which the chlorine industry expanded most rapidly.<sup>26</sup> Then, during the 1970s, many governments restricted the use of leaded gasoline (which contains chlorinated additives and thus produces dioxin when burned) and major applications of some dioxin-contaminated pesticides, including 2,4,5-T and pentachlorophenol. In the same period, the U.S. Clean Air Act and similar legislation in other nations required a wide range of industrial facilities (such as chemical plants, incinerators, and steel mills) to install particulate-reducing pollution control devices, which are likely to have reduced dioxin emissions to the air, as well. Following those actions, dioxin releases to the air—as measured by dioxin accumulation in plant foliage<sup>27</sup>—declined by nearly 80 percent between the late 1970s and the early 1990s. As one might expect, dioxin levels in the milk of cows, which eat foliage, subsequently declined, falling by about 25 percent between 1990 to 1994.<sup>28</sup> Because annual sediment layers primarily reflect the deposition of dioxin from the air into surface waters, dioxin concentrations in most samples of marine and freshwater sediment also declined.<sup>29</sup>

But declining deposition rates do not necessarily mean a lower total burden of pollutants in the environment. Sediment layers provide a reasonably reliable record of the quantity of a substance that settles to the bottom of a body of water in any year, which roughly indicates the amount that entered the water in that year. The annual flux of persistent compounds, however, is not directly related to the total environmental burden; if the rate at which one puts marbles into a jar declines from 100 per year to 50, the total number of marbles in the jar will continue to increase. For a record of the total amount of dioxin that has accumulated in the environment over time, soils are better indicators than sediments, because pollutants from the recent and the distant past stay near the top of the soil, rather than being buried in annual layers. British scientists have found that dioxin levels in soil, unlike those in sediments and foliage, continued to increase without interruption right through the 1980s and into the early 1990s. They concluded, "PCDD/Fs are persistent in soils, such that declines in atmospheric deposition may not result in a decline in the UK PCDD/F burden for some time. It may be that

If there is a threshold for dioxin, it is so low that it is irrelevant for the purposes of environmental policy and health protection.

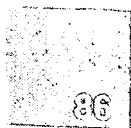
These pollutants are so persistent that, so long as releases continue somewhere, the global environmental burden of these compounds declines slowly, if at all.

even with the anticipated declines in the primary emissions of PCDD/Fs over the next decade, the rate of deposition may still exceed the rate of loss from soils."<sup>30</sup>

Human and wildlife tissues reflect the same pattern, with a delay because of the persistence of these compounds in our bodies. Dioxin levels in several species of wildlife in the Great Lakes declined during the late 1970s, 1980s, and early 1990s.<sup>31</sup> By 1993, however, levels of dioxins in the eggs of Great Lakes trout had stopped falling, reaching, in the words of one group of researchers, "a steady state or a very slow decline."<sup>32</sup> No human tissue analyses are available from the early decades of this century, but dioxin levels in people from the United States increased steadily during the 1960s. Following the regulatory actions of the 1970s, levels declined during the 1980s.<sup>33</sup> Concentrations continued to fall in most European nations during the 1990s, although the data for the United States are ambiguous.<sup>34</sup>

There are no reliable projections of future trends in dioxin levels. Apparently, the successful actions of the past have had their effect, however. According to Swedish scientists, the declines are history, not a continuing trend. "During the last twenty years an overall decrease in the levels [of dioxin in human tissues] is recorded. The major part of this decrease dates back to the late 1970s and the early 1980s. The situation of today seems to be quite constant and resembles what has been found for PCB. Analyses of human breast milk show a similar trend."<sup>35</sup> In Germany, dioxin levels in human milk have stopped falling and increased slightly in the late 1990s.<sup>36</sup>

All this information suggests a pattern with clear implications for policy. Action to reduce production and use of dioxin-generating substances has reduced emissions to the environment of these compounds. On local and regional scales, contamination of the environment and the tissues of living organisms has fallen in response, with the speed of the decline varying among different kinds of sampled material. But these pollutants are so persistent that, so long as releases continue somewhere, the global environmental burden of these compounds declines slowly, if at all. If we allow releases to continue at a reduced rate, concentrations will stop





declining when a new steady state is reached. If we want to reduce human and wildlife exposure, we should reduce the use of dioxin-generating materials rapidly. Because infinitesimal doses of dioxin are enough to cause health damage, the only level of dioxin exposure that should be considered acceptable from a public health perspective is zero. If we want to prevent the accumulation of dioxins and other persistent toxic chemicals in the global environment, we need to stop environmental releases altogether.

## PHthalATES

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### Usage

Concern has recently focused on phthalates, a class of compounds used as plasticizers in flexible PVC. Phthalates are organic chemicals used to make vinyl plastic flexible, and they can make up a large portion—up to 60 percent by weight—of the final product.<sup>37</sup> Flexible PVC—including flooring and wall coverings—accounts for just more than half of all vinyl demand, while the remainder is rigid, unplasticized materials like pipes and siding.<sup>38</sup> PVC accounts for the vast majority of all phthalate consumption, and phthalates are the dominant class of plasticizers used in soft vinyl products.<sup>39</sup> An estimated 50 percent of all phthalates produced are used in building and interior materials.<sup>40</sup> About 5.4 million tons of phthalates are used in vinyl products worldwide each year.<sup>41</sup> Vinyl is the only major plastic that requires phthalates to be flexible.

Four specific phthalates are used extensively in PVC and are relevant to this discussion: diethylhexyl phthalate (DEHP; U.S. production near 2 million tons per year), diisononyl phthalate (DINP; 178,000 tons per year), butylbenzyl phthalate (BBP; production not reported), and diisodecyl phthalate (DIDP; 135,000 tons per year). In addition, di-n-octyl phthalate is formed as a by-product of the production of other phthalates that are used in PVC and is released to the environment during the manufacture and use of flexible PVC.<sup>42</sup> The other commercially important phthalates dibutyl phthalate (DBP) and dioctyl phthalate (DOP) are not used appreciably in PVC.

Because infinitesimal doses of dioxin are enough to cause health damage, the only level of dioxin exposure that should be considered acceptable from a public health perspective is zero.

Because phthalates are fat-soluble, they cross the placenta easily and concentrate in breast milk.

#### Fate, occurrence, and exposure

Phthalates are moderately persistent in the environment. They can be degraded biologically or chemically in the presence of air in days or weeks; in anaerobic conditions, like those often found in groundwater, little if any degradation occurs, with a hydrolysis half-life of 2000 years.<sup>43</sup> Because phthalates are soluble in fat, they quickly adsorb into sediments or enter the food chain, where they can bioaccumulate.<sup>44</sup> Although some phthalates are partially metabolized in humans, DEHP tends to bioaccumulate in aquatic invertebrates and fish. Bioconcentration factors measured in fish range from 42 to 2680, indicating that fish swimming in water contaminated with DEHP accumulate in their tissues levels of DEHP that are up to thousands of times greater than the concentration in the water.<sup>45</sup>

Because of this behavior and the large quantities produced, phthalates have become ubiquitous environmental contaminants, present in air, water, fish, and human tissues on a global basis.<sup>46</sup> Because most phthalates are more soluble in fat than air or water, levels in outdoor air and water are typically low, although considerably higher levels of some phthalates occur in indoor air;<sup>47</sup> levels of DEHP and metabolites in animal and human tissues can be quite high, reaching concentrations higher than such infamous pollutants as PCBs and DDT.<sup>48</sup>

For the general population, the greatest exposures to phthalates come through the food supply, with the highest levels in fatty foods like dairy, fish, meat, and oils, although indoor air contributes substantially as well.<sup>49</sup> Because of their higher rate of food consumption per kilogram of body weight, children ages 6 months to 4 years receive the highest exposures to phthalates, with a daily dose of DEHP (19 micrograms per kilogram of body weight) that is more than three times that of the average adult.<sup>50</sup> A recent U.S. Centers for Disease Control study analyzed urine samples from the general U.S. population and found surprisingly high levels of metabolites of BBP, DEHP, DINP, and DnOP (137, 21.5, 7.3, and 2.3 ppb, respectively), reflecting "considerable exposure" to these compounds, as well as other phthalates.<sup>51</sup> Because phthalates are fat-soluble, they cross the placenta easily and concentrate in breast milk.<sup>52</sup> The authors of the CDC study concluded, "Some individual exposures


are substantially higher than previously estimated for the general population," and these "data indicate a substantial internal human dose of DBP, DEP, and BBP, [the metabolites of which] are of particular concern because of their developmental and reproductive toxicity in animals."<sup>53</sup>

### Health impacts

Phthalates are well-recognized developmental and reproductive toxicants. DEHP is the most studied member of the class, and in studies of a variety of species of laboratory animals, relatively high doses of DEHP produce structural birth defects, developmental delay, and intrauterine death. DEHP also reduces estrogen levels, fertility, and ovarian weight, and it suppresses ovulation in female rodents. In males, DEHP causes testicular lesions, reduced androgen levels, and atrophy of the testes. Exposure in utero or during childhood is particularly problematic—developmental effects occur at doses up to 100 times lower than those that produce reproductive toxicity in the adult.<sup>54</sup> Exposure of a pregnant mother rat to DBP or DEHP disrupts the development of her male offspring's reproductive system; effects include reduced synthesis of testosterone by the fetal testis, loss of sperm-producing cells, and abnormal development of the testes, epididymes, and prostate.<sup>55</sup> Extremely low levels of MEHP (100 nanomolar, or less than 30 ppb)—approximately the same level as found in the urine of the general U.S. population<sup>56</sup>—cause significant damage to cultured sperm-producing cells of developing rat testes.<sup>57</sup>

The general human population is exposed to levels of DEHP that justify public health concern. EPA's reference dose (RfD) for DEHP is 20 micrograms per kilogram of body-weight per day.<sup>58</sup> An RfD is the "acceptable" exposure level, predicted by EPA based on toxicological studies, at which significant risk of health effects will not occur. But the average daily dose in the United States for children ages 6 months to 4 is 19 micrograms per kilogram of body weight, approximately the same as EPA's RfD.<sup>59</sup> And researchers at the Centers for Disease Control have estimated that the daily DEHP exposure of adults in the general U.S. population, based on the 95th percentile and maximal levels found in the general population's urine, is as high as 3.6 and 46 micrograms per kilogram per day—in the same range as EPA's RfD, and considerably higher for some individuals.<sup>60</sup>

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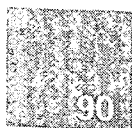
  
The general public's DEHP  
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These results make clear that the general public's DEHP exposure allows little or no clear margin of safety. Furthermore, EPA's RfD for DEHP was established in 1986 based on a 1953 study that examined changes in liver weight in rodents exposed to DEHP, supplemented by other studies from 1982 and 1984. This RfD was calculated before any of the relevant studies of the effects of chronic low-level exposure to DEHP and metabolites on reproduction and development were published. Since these types of impacts may occur at substantially lower doses than liver damage, even the RfD may not represent a truly safe dose.<sup>61</sup> It is therefore prudent from a public health perspective to reduce exposures to DEHP as rapidly as possible.

Considerably less research has been conducted on the toxicity of other phthalates, but some data are available. Like DEHP, BBP is a male reproductive toxicant, causing testicular lesions, reduced sperm counts, and increased infertility at relatively high doses in adult males—but virtually no data are available on impacts on the development of the reproductive system.<sup>62</sup> Monobutyl phthalate, a metabolite of BBP, causes cryptorchidism (failure of the testes to descend) when exposure occurs in utero.<sup>63</sup> Much more data needs to be gathered before the full suite of effects caused by each phthalate, together with the dose required to produce these effects at different stages of development, will be understood.

In 2000, an expert committee convened by the National Toxicology Program reported its review of the evidence on the reproductive and developmental toxicity of phthalates. The panel compared the doses of DEHP that produce developmental toxicity in animals to the levels to which infants and toddlers in the general U.S. population are routinely exposed, and concluded a "concern that exposure may adversely affect male reproductive tract development."<sup>64</sup> The panel also examined exposure that occurs across the placenta and via breast milk and concluded, "The panel has concern that ambient oral DEHP exposures to pregnant or lactating women may adversely affect the development of their offspring." Based on the available data, the panel expressed low, minimal, or negligible concern about other phthalates.

There are few epidemiological data concerning the impacts of phthalates on human development and reproduction. One study suggests that



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phthalate exposure of the general population may be related to endocrine disruption and altered reproductive development in girls. In Puerto Rico, the incidence of premature breast development (early thelarche, defined as breast development during the period from 2 to 8 years of age) is quite high (about 1 percent of the population) and has been rising rapidly in recent decades. This phenomenon cannot be explained by changes in nutrition or exposure to hormones used in agriculture,<sup>65</sup> and a similar trend has been documented in the United States.<sup>66</sup> Exposure to endocrine-disrupting compounds is one plausible explanation, because estrogens trigger breast development in girls. A case-control study of girls from the general Puerto Rican population found that the levels of phthalates in the blood of girls with premature breast development were 5.9 times higher levels than in girls without premature development. Levels of DEHP, which accounted for more than 80 percent of the total phthalates measured in the girls' blood, were 6.4 times higher among girls with premature thelarche. This study does not prove that phthalates caused the precocious sexual development, but, as the authors concluded, it suggests that the estrogenic or other endocrine-disrupting effects of phthalates may have contributed to the epidemic of early thelarche.<sup>67</sup>

Some phthalates may be carcinogens. According to the National Toxicology Program (NTP), DEHP is "reasonably anticipated to be a human carcinogen" based on consistent findings of liver cancer in laboratory animals. There has been some debate about whether the mechanism of carcinogenicity in rodents is relevant to humans. Based on this issue, the International Agency for Research on Cancer now lists DEHP as an animal carcinogen but as unclassifiable with regard to human carcinogenicity. But the NTP has not adopted this view, and scientists at the National Institute for Environmental Health Scientists have criticized the IARC's action as lacking a sound scientific basis in current understanding of DEHP's mechanism of toxicity.<sup>68</sup>

## TRENDS IN PVC MARKETS

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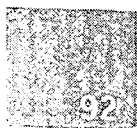
Polyvinyl chloride plastic was first marketed in 1936<sup>69</sup> but did not begin to play a major role in building construction until the 1950s. Production

Few materials have infiltrated modern life as ubiquitously as PVC, and construction represents the largest sector of vinyl applications.

grew rapidly from the 1960s through the 1980s, and has now reached more than 30 million tons per year. This estimate includes the non-PVC components of vinyl products, such as plasticizers and stabilizers; production of pure polyvinyl chloride is now estimated at approximately 24 million metric tons per year worldwide.<sup>70</sup> Vinyl is the largest use of chlorine in the world, accounting for more than 40 percent of all chlorine use in the United States, with a similar or slightly greater proportion globally.<sup>71</sup>

Few materials have infiltrated modern life as ubiquitously as PVC, and construction represents the largest sector of vinyl applications. In the past fifty years, vinyl—the only major plastic that contains chlorine—has taken the place of ceramics, metals, textiles, and wood in a range of building products, including exterior siding, floor tiles, pipes, wall coverings, window frames, and wire and cable sheathings. PVC is also used in appliance casings, furniture, shower curtains, toys, upholstery, and other household items, as well as in automobile and other vehicle components, medical devices, office supplies, and packaging.

Today, PVC is not only the largest but also the fastest growing use of chlorine in the world. In fact, it is the only major chlorine application still increasing in the world's wealthy nations, and it is growing particularly rapidly in developing countries.<sup>72</sup> The reasons for the industry's aggressive expansion of PVC markets lie in the economics of the production of chlorine and its coproduct, sodium hydroxide (caustic soda or alkali). Alkali is a profitable and environmentally unproblematic substance that is used as a source of sodium and hydroxide ions in a wide variety of industries. The majority of the world's alkali is produced by chlor-alkali electrolysis, in which chlorine and sodium hydroxide are produced together in a fixed ratio. Chlorine is a hazardous gas, so it cannot be safely stored; the chemical industry therefore can only produce as much alkali as there are markets for chlorine. In recent years, as numerous uses of chlorine (for example, pulp and paper, refrigerants, and solvents) have been restricted for environmental reasons, a chlor-alkali imbalance has developed, requiring the industry to create new markets for chlorine in order to continue potential sales in alkali markets.<sup>73</sup> According to an analyst for the chlor-alkali manufacturer Elf-Atochem, "There is a logical progression toward permanent imbalance between



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caustic supply and demand. Domestic chlorine consumption and chlorinated exports will set operating rates for U.S. chlor-alkali capacity, with the EDC/VCM/PVC chain leading the way."<sup>74</sup>

The industry's strategy to rectify the chlor-alkali imbalance is the aggressive expansion of markets for PVC and the feedstocks from which it is made—already the major global sinks for chlorine. For the past several decades, PVC production and consumption has grown at a remarkable pace, but recently PVC markets in industrialized nations have neared saturation. Vinyl has already replaced so many traditional materials, that growth in vinyl in these countries is now no greater than annual increases in gross national product.<sup>75</sup> This rate of growth is not nearly enough to offset the loss of chlorine demand in sectors that have been restricted so the industry has focused on expanding exports of PVC and its feedstocks to developing nations.<sup>76</sup> U.S. net exports of EDC, PVC, and VCM now contain about two million tons of chlorine per year—more than 15 percent of total chlorine production—and were expected to grow by a stunning 14 percent in 1998 alone.<sup>77</sup> The major recipients are Latin America and Asia, where PVC consumption is expected to grow at annual rates of 7 percent or more per year, leading to a doubling of demand each decade.<sup>78</sup> Why these countries? As an executive of a major Japanese PVC company explained, vinyl is a uniquely marketable product for export because poor countries need to reach only minimal levels of economic and technological development before they can be encouraged to buy plastic, and these nations usually have few environmental regulations:

Demand for PVC in the high-population developing countries will grow rapidly after their GNP per capita reaches \$500 per year. On the other hand, in the world's major industrialized countries where per capita GNP is over \$10,000/year, the use of PVC has come close to its maturity, and the growth rate of PVC may not be as much as the GNP growth rate. The concern about the disposal of waste material is one of the reasons for advanced society to refrain from excessive use of plastics.<sup>79</sup>

The rapid increase in vinyl consumption in developing countries means that, despite slow growth in PVC consumption in the wealthy nations,

The reasons for the industry's aggressive expansion of PVC markets lie in the economics of the production of chlorine and its coproduct, sodium hydroxide.

global demand for PVC will rise from 22 million tons per year in 1996 to 28 million tons per year 2000—an annual growth rate of more than 6 percent.<sup>80</sup> According to one industry analyst,

The most important structural changes [in the chlorine industry] will be concentration of growth in emerging markets and restructuring in industrialized markets; potential loss of 10–30 percent of current customers in industrialized markets; continued shutdown of inland plants linked to declining uses; three quarters of global demand growth in developing countries; increase in VCM and PVC trade and potential tripling in volume of global EDC trade. It appears unlikely at this point that lost markets will offset growth for PVC and other uses.<sup>81</sup>

## Notes

1. Thornton 2000; Colborn et al. 1996.
2. Tatsukawa and Tanabe 1990; Allan et al. 1991.
3. Gregor and Gummer 1989; Patton et al. 1991; Barrie et al. 1997.
4. Simonich and Hites 1995.
5. Ono et al. 1987.
6. Dewailly et al. 1993; Norstrom et al. 1990.
7. Great Lakes Water Quality Board 1987.
8. Barrie et al. 1997.
9. Fuhrer and Ballschmitter 1998.
10. Brun et al. 1991.
11. DeLorey et al. 1998; Makhijani and Gurney 1995; Plumacher and Schroder 1993.
12. EPA 2000a.
13. Onstot et al. 1987.
14. National Research Council 2000; Guillette and Crain 1999.
15. National Research Council 2000.
16. EPA 2000a.
17. EPA 2000a.
18. McGregor et al. 1998; National Toxicology Program 2001.
19. Following EPA's usual approach, this risk estimate is based on the upper bound of the 95 percent confidence interval for the carcinogenic potency of dioxin. The potency is derived from both human and animal studies.
20. See discussion in EPA 2000a, as well as DeVito et al. 1995 and Tryphonas 1995.
21. See also Tritscher et al. 1994; Kohn et al. 1996; Portier et al. 1996.
22. Peterson et al. 1992.
23. Neubert and colleagues (1991) documented this effect in primate lymphocytes at TCDD concentrations as low as 10–14 moles per liter.
24. Kerkvliet (1994) reports that TCDD concentrations in the spleen as low as  $2 \times 10^{-15}$  moles per liter caused immunotoxicity in laboratory rats.
25. See for example Olsson et al. 1994; Reijnders 1986; de Swart et al. 1996; Giesy et al. 1994a and 1994b.
26. Alcock and Jones (1996) provide an excellent review of dioxin trends. Specific papers include Czuczwa and Hites 1984, 1985 and 1986. Czuczwa et al. 1984. Juttner et al. 1997, Kjeller and Rappe 1995, Kjeller et al. 1991, and Kjeller et al. 1996.
27. Kjeller et al. 1996.
28. Reviewed in Alcock and Jones 1996.
29. Sediment cores from two Black Forest lakes, for example, show a contradictory pattern. One shows that dioxin levels in the layer dated 1985–1992 were lower than in that from the period 1964–1985. The other, however, shows that dioxin levels in 1982–1992 were higher than in 1960–1982. (Juttner et al. 1997).
30. Alcock and Jones 1996. Kjeller et al. 1991 also provide a useful discussion.
31. Allan et al. 1991. Alcock and Jones (1996) also review studies that suggest a decline in PCDD/Fs in Baltic wildlife during the same period.



32. Huestis et al. 1997.
33. Stanley et al. 1990.
34. LaKind et al. 2001.
35. Johansson 1993.
36. Furst 2000.
37. DTI 1995.
38. These figures are for Western Europe (European Commission 2000).
39. DTI 1995.
40. Oje et al. 1997.
41. My calculations are extrapolated from the figures for Sweden, where the phthalate input into PVC equals 22.6 percent (TNO Centre for Technology and Policy Studies 1996), assuming 24 million tons of vinyl produced per year worldwide.
42. National Toxicology Program 2000.
43. HSDB 1997.
44. National Toxicology Program Center for the Evaluation of Risks to Human Reproduction 2000a, 2000b, and 2000c.
45. HSDB 1997.
46. Giam et al. 1978; Blount et al. 2000; HSDB 1997.
47. National Toxicology Program Center for the Evaluation of Risks to Human Reproduction 2000a.
48. Giam et al. 1978; National Toxicology Program Center for the Evaluation of Risks to Human Reproduction 2000a.
49. National Toxicology Program Center for the Evaluation of Risks to Human Reproduction 2000a.
50. National Toxicology Program Center for the Evaluation of Risks to Human Reproduction 2000a.
51. Blount et al. 2000.
52. National Toxicology Program Center for the Evaluation of Risks to Human Reproduction 2000a.
53. Blount et al. 2000.
54. National Toxicology Program Center for the Evaluation of Risks to Human Reproduction 2000a.
55. Gray et al. 1999; Lambright et al. 2000.
56. Blount et al. 2000.
57. National Toxicology Program Center for the Evaluation of Risks to Human Reproduction 2000a.
58. EPA 2000b.
59. National Toxicology Program Center for the Evaluation of Risks to Human Reproduction 2000a.
60. Kohn et al. 2000. The median exposure level was estimated to be 0.71 micrograms per kilogram per day.
61. EPA 2000b.
62. National Toxicology Program Center for the Evaluation of Risks to Human Reproduction 2000b.
63. Imajima et al. 1997.
64. National Toxicology Program Center for the Evaluation of Risks to Human Reproduction 2000a.
65. Colon et al. 2000.
66. Hermann-Giddens et al. 1997.
67. Colon et al. 2000.
68. Melnick 2001.
69. Taylor 1957; Aftalion 1991.
70. Kielhorn et al. (2000) report global vinyl chloride production capacity of 27 million tons per year. Assuming 95 percent utilization of VCM in PVC and 95 percent operating rates, global PVC production is likely to be about 24 million tons per year.
71. Leder et al. 1994.
72. Growth is expected in a few much smaller applications, such as phosgene for polycarbonate and propylene chlorohydrin for propylene oxide, but the increases in these chlorine uses are less than one-tenth the growth expected in PVC (Mears 1995).
73. Leder et al. 1994.
74. Tullos 1995.
75. Endo 1990.
76. Leder et al. 1994.
77. Mears 1995.
78. Waltermire 1996.
79. Endo 1990.
80. Svalander 1996.
81. Tittle 1995.

## Conclusion



## Conclusion

The PVC lifecycle presents one opportunity after another for the formation and environmental discharge of organochlorines and other hazardous substances. When its entire lifecycle is considered, it becomes apparent that this seemingly innocuous plastic is one of the most environmentally hazardous consumer materials produced, creating large quantities of persistent, toxic organochlorines and releasing them into the indoor and outdoor environments. PVC has contributed a significant portion of the world's burden of persistent organic pollutants and endocrine-disrupting chemicals—including dioxins and phthalates—that are now present universally in the environment and the bodies of the human population. Beyond doubt, vinyl has caused considerable occupational disease and contamination of local environments as well.

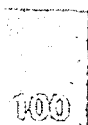
In summary, the feedstocks, additives, and by-products of the PVC lifecycle are already present in global, local, and workplace environments at unacceptably high levels. Efforts to reduce the production and release of these substances should be environmental and public health priorities. The hazards posed by dioxins, phthalates, metals, vinyl chloride, and ethylene dichloride are largely unique to PVC, which is the only major building material and the only major plastic that contains chlorine or requires plasticizers or stabilizers. PVC building materials therefore represent a significant and unnecessary environmental health risk, and their phase-out in favor of safer alternatives should be a high priority.

**PVC is the antithesis of a green building material. Efforts to speed adoption of safer, viable substitute building materials can have significant, tangible benefits for human health and the environment.**

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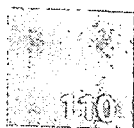
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# **The Economics of Phasing Out PVC**

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Rachel Massey

December 2003

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## Executive Summary

Polyvinyl chloride, also known as PVC or “vinyl,” has become one of the most widely used plastics today. We encounter PVC on a daily basis in products ranging from toys, packaging, and lawn furniture to water and sewer pipes, medical equipment, and building materials.

PVC poses hazards to human health over the course of its life cycle. PVC production exposes workers and communities to vinyl chloride and other toxic substances. PVC products such as medical equipment and children’s toys can leach toxic additives during their useful life. Vinyl building materials release hydrochloric acid fumes if they catch fire, and burning PVC creates byproducts including dioxin, a potent carcinogen.

The health hazards associated with the production, use, and disposal of PVC are, for the most part, avoidable. Alternatives are available across the range of PVC products. In some cases the alternatives are no more expensive than PVC; in other cases there is a small additional cost. Often there are good reasons to expect the costs of alternatives to decline over time.

### Vinyl today: a look at the market

PVC sales reached 14.4 billion pounds in the US and Canada in 2002, or 46 pounds per person. Worldwide production was around 59 billion pounds, or an average of 9 pounds per person. With 5 percent of the world’s population, the US and Canada consume 24 percent of the world’s PVC. The principal uses of PVC in North America, in order of importance, are pipes, construction materials, consumer goods, packaging, and electrical products (such as wire and cable insulation).

Three in-depth studies have estimated the costs of phasing out PVC. The latest one, a 1997 study by Environment Canada, based on a detailed analysis of the cost of alternatives, suggests an average annual cost of \$0.55 per pound. If this estimate still applied today, it would imply a total cost of \$8 billion per year, or \$25 per person, to phase out PVC in the US and Canada. Correction for one obviously dated assumption in that study cuts the estimate in half, to \$4 billion total or \$12 per person. However, there are several reasons to expect that the costs of alternatives will be still lower and will decline over time.

### Factors favoring phaseout

Figures such as those from Environment Canada, based on current market prices alone, overstate the economic benefits of PVC. We explore four major economic reasons why this is the case.

- *Life-cycle costs often favor alternatives.* Some of the alternatives have higher initial purchase prices than PVC products, but are actually less expensive over the useful life of the product. Commercial flooring provides an example: among the flooring options we examined, vinyl has the lowest installed cost; but due to its shorter lifetime and higher maintenance requirements, it has the highest life-cycle cost. In such cases, rather than making a decision based on initial costs alone, purchasers can save money by comparing the full costs over the product life cycle of buying, installing, using, maintaining, and ultimately disposing of alternative products.
- *Mass production reduces costs.* Most products are cheaper when they are produced in large quantities; costs typically drop as production volumes increase. Currently the advantages of mass production favor PVC: many PVC products have achieved huge volumes, making them look cheap today. However, the alternatives to PVC could likewise grow in volume in the future, making them less expensive and more competitive than they are at present.
- *PVC products endanger their users.* The harmful effects of PVC are sometimes felt by the users of the product, as in the case of some PVC medical supplies. In case of fire, vinyl building products begin to smolder long before they burn, releasing toxic fumes of hydrochloric acid, and thereby threatening building occupants and firefighters. For this reason, the International Association of Firefighters supports efforts to reduce PVC use.

Related hazards could occur with PVC-insulated wiring, which was once standard for use in airplanes. There is no proof that PVC insulation has ever caused a plane crash, but some investigators have suggested that there are grounds for concern about older planes that are still flying with PVC-insulated wires.

- *Environmental protection costs are routinely less than anticipated.* Academic research has shown that the actual costs of compliance with environmental standards are often lower than the predicted costs. The strict standard for workplace exposure to vinyl chloride, the raw material for PVC production, established in 1974 by the Occupational Safety and Health Administration, led to profitable innovation, not vast economic losses (as predicted by industry when the standard was proposed). A recent study of the costs of controlling chlorinated pollutants confirms the pattern of advance overestimation of environmental management costs.

### Markets for alternatives

Because PVC is used in such a diverse range of products, the nature of the alternatives and the likely costs of a phaseout differ from one market to the next. However, there are affordable alternatives in every market we have examined. We discuss alternatives to PVC in selected commercial and institutional markets, including pipes, roofing, floor coverings, and medical gloves, followed by a brief look at residential siding and windows, the largest-volume vinyl building products.

- *Pipes.* Almost half of the PVC manufactured in the US and Canada is used to make pipes and tubing, a diverse category spanning several distinct end uses. For municipal water and sewer pipes, PVC competes with traditional materials including iron, concrete, and vitrified clay, as well as with polyethylene (PE), a less toxic plastic that has a growing share of the market. Sales of PE pipe (for all uses) have reached about one billion pounds annually, compared to 6.5 billion pounds of PVC pipe. PE and traditional pipe materials perform better than PVC in cold climates and under high pressure; in addition, PE pipe is virtually leak-free. Factors like these are often decisive; many municipalities and water companies make decisions based on the desired physical properties of pipes rather than the differences in material prices.

Inside buildings, PVC has become common for electrical conduits and particularly for the “drain/waste/vent” pipes that carry water and waste away. Due to concerns about fire hazards, some building codes limit the use of plastic pipe in multi-story buildings; even where it is allowed, the additional requirements for fireproofing offset much of the apparent cost advantage of PVC pipe.

A case study in Austin, Texas, found that using copper, cast iron, and polyethylene plumbing rather

than PVC throughout a large new building increased plumbing costs by 15 percent over all. Costs for small-diameter pipes of several varieties show modest cost differences; PVC has the lowest installed cost in some but not all applications.

- *Roofing.* In roofing, PVC competes primarily with two less toxic synthetic materials, ethylene propylene diene monomer (EPDM) and thermoplastic elastomer polyolefin (TPO), in the market for single-ply (single-layer), low-slope roofs. EPDM is by far the market leader among the three, and PVC is third in sales volume, slightly behind TPO. Advantages claimed for PVC, particularly the fact that it is available in white and therefore provides good reflectivity in hot weather, are equally available with alternative materials. PVC roofing also has a shorter lifetime than most alternatives and presents special technical problems, such as cracking and loss of flexibility under some circumstances.

An analysis of construction costs in Austin, Texas shows that both of the alternatives have lower installed costs than PVC. This is true for a range of membrane thicknesses and modes of installation. These cost relationships are echoed by data from Chicago and western Massachusetts, supporting the view that the differences are not specific to one region or climate.

- *Flooring.* For commercial and institutional flooring, PVC competes with a variety of materials, ranging from natural cork and traditional linoleum to economical synthetic rubber products, and new non-chlorinated polymers that match the look of vinyl. While vinyl flooring has the lowest first cost among the 12 flooring products we examined, its relatively short lifetime and high maintenance requirements outweigh this advantage; it is the most expensive option on a life-cycle basis. An analysis by the US Navy of two flooring options for high-traffic areas on its ships reached the same conclusion: on a life-cycle basis vinyl was far more expensive than Stratica, a durable new polymer. “Green building” efforts have often used linoleum floors as a natural, non-toxic alternative to vinyl, as seen in our case studies; linoleum and other materials provide viable alternatives to vinyl flooring under many circumstances.

- *Gloves.* A variety of disposable medical supplies can be made from PVC. We examine the case of medical gloves. Latex, which for a long time was the standard material of choice for medical examination and surgical gloves, has come to pose a serious health hazard with rising rates of latex

allergies. In this context, health care institutions must move to alternative glove materials; PVC and nitrile are the principal candidates. While PVC gloves are cheaper than nitrile gloves, their lower price is counterbalanced by their lower durability. One study found PVC gloves to have a 30% failure rate under simulated use conditions, compared to 2% for both latex and nitrile. Correction for the failure rate offsets one-third of the apparent cost advantage of PVC over nitrile gloves, based on prices quoted to us by a leading distributor. Kaiser Permanente, the nation's largest not-for-profit health care organization, concluded from its internal review that nitrile gloves were cost-competitive with PVC due to their greater durability, and bought 43 million pairs of nitrile gloves.

- *Siding and windows.* Vinyl is now the most common siding material for low- and moderate-priced housing. However, wood shingles or clapboard also offer viable siding alternatives, as do fiber cement and simulated stucco. Disadvantages to vinyl siding include poor resistance to temperature, vulnerability to water damage, and chemical hazards when it burns or smolders. Despite claims that vinyl is "maintenance free," vinyl can fade with time, can require painting, and can warp. Fiber cement, a relatively new product, is more durable than vinyl and almost as low-maintenance; moreover, fiber cement does not warp or burn.

Alternatives to PVC windows include wood, fiberglass, and aluminum windows. Problems with vinyl windows include sensitivity to high and low temperatures, possible brittleness, and health hazards in case of fire. Vinyl windows can be energy efficient, but they can expand and contract, causing the seal of the window to break; in this case, they cannot be repaired, and must be replaced.

### **Employment effects of a PVC phaseout**

There are 126,000 workers in PVC fabrication plants in the US; we estimate that there are no more than 9,000 workers making vinyl chloride and PVC resin. Replacing PVC with alternatives will change some of these jobs: from fabricating PVC products to fabricating the same products from other materials, most often other plastics; or from making vinyl chloride and PVC resin to making safer substitutes. However, the alternatives are likely to require about the same total employment as production of PVC. In some cases, the same workers who currently make PVC products will be employed making products from PVC alternatives.

### **Steps toward alternatives**

Around the world and throughout the US, a variety of community, state, and national government initiatives have been undertaken to promote the use of safer alternatives to PVC. Many health care institutions have made statements on the need to reduce or eliminate PVC use. The auto industry and other major industries have taken numerous steps to incorporate alternatives to PVC into their products. In addition, countless innovative construction projects have demonstrated the practicality of reducing or eliminating PVC use. Examples discussed here include a green building initiative carried out by a volunteer group, GreenHOME, in partnership with Habitat for Humanity; the Erie Ellington Homes in the Dorchester neighborhood of Boston; the Sheraton Rittenhouse Square Hotel in Philadelphia; and innovative projects by religious communities.



## Introduction

### Why Worry About PVC?

Polyvinyl chloride has grown from a little-known material with a few specialized uses in the mid-twentieth century (used by the Navy for waterproofing in World War II, for example) to become one of the most widely used plastics today.<sup>1</sup> Thanks to low prices and aggressive marketing, polyvinyl chloride, also known as PVC or "vinyl," has become ubiquitous in our homes and communities. We encounter PVC on a daily basis in products ranging from children's toys, packaging, and lawn furniture to water and sewer pipes, medical equipment, and building materials.

Unfortunately, PVC poses hazards to human health over the course of its life cycle. We review these hazards only briefly here, as other sources present them in detail.<sup>2</sup>

**PVC production:** Vinyl chloride, the building block from which PVC resin is made, is classified by the National Toxicology Program as "known to be a human carcinogen," and has been similarly classified as a human carcinogen by other US and international agencies.<sup>3</sup> PVC production exposes workers and communities to vinyl chloride,<sup>4</sup> and many studies have documented links between working in vinyl chloride production facilities and increased likelihood of developing diseases including angiosarcoma of the liver, a rare form of liver cancer.<sup>5</sup> The large numbers of workers in PVC manufacturing facilities, where vinyl chloride exposure is generally lower than in vinyl chloride and PVC resin production, also have an increased likelihood of developing angiosarcoma of the liver.<sup>6</sup> Vinyl chloride and PVC exposure are also associated with certain non-cancer disorders.<sup>7</sup>

**PVC use:** For most applications, PVC resins are mixed with additives such as stabilizers, plasticizers, and fillers.<sup>8</sup> These additives can leach out of, or volatilize from, a PVC product during the product's useful life. For example, exposure to plasticizers can occur when they volatilize from PVC products, such as building materials; when they leach out of medical equipment during use, exposing patients; and when they leach from soft plastic toys.<sup>9</sup> Phthalates, which are used as plasticizers, may pose hazards to development and reproduction,<sup>10</sup> and have been implicated in the development of respiratory problems in children.<sup>11</sup> Stabilizers that are used in PVC products include lead and other heavy metals.

**PVC disposal and accidental burning:** When vinyl building materials catch fire—or even smolder, before igniting—they can release acutely toxic hydrochloric acid fumes.<sup>12</sup> At the end of its life, PVC can release toxic substances into the environment when it is burned in an incinerator or rural trash barrel, and can leach toxic stabilizers and plasticizers when it is buried in a landfill. Dioxins, which threaten human health at extraordinarily low concentrations, can be released when PVC is burned, either intentionally or accidentally.<sup>13</sup>

In the face of these and related concerns, vinyl advocates argue that the material offers not only low prices but also amazing convenience. PVC promises to provide "maintenance-free" building exteriors, easily installed pipes and plumbing, low-cost coverings for floors and walls, and all manner of molded or flexible plastic objects. It is widely believed that giving up PVC would impose a painful burden on the economy.

Our principal finding is that this belief is untrue; PVC does *not* offer enormous economic advantages over all other materials. Alternatives providing equal or better performance are available for almost every use of PVC. In some cases, the costs of the alternative materials are already comparable to PVC when costs are measured over the useful life of the product. In other cases, the alternatives are slightly more expensive at present, but are likely to come down in cost as their market share expands. The continued use of PVC offers small short-term gains in some areas, and none at all in others.

In this report, we explore the economics of phasing out PVC. We begin by looking at the uses of PVC today and reviewing past studies of the costs of alternatives to PVC. We then offer four principles for analysis of the alternatives, all of them challenging the economic arguments for continued use of PVC:

- Alternatives that have higher purchase prices, or higher installed costs, than PVC may still be cheaper on a full-cost accounting or life-cycle cost basis.
- Alternatives that look expensive when produced in small batches today will become cheaper when they are mass-produced.
- The unique health and environmental damages caused by PVC can endanger the users of a product, as in the case of medical supplies.

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o/o of  
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- Academic studies have shown that the costs of environmental protection are routinely overestimated in advance, and decline rapidly after implementation.

We apply these principles in a discussion of alternatives to PVC in major markets, including detailed discussion of pipes, roofing, floor coverings, and medical gloves, and a summary description of the siding and windows markets. Following the analysis of these markets, we examine the expected employment effects of a PVC phaseout and then turn to the steps that have already been taken toward alternatives.

### *Vinyl Today: A Look at the Market*

Sales of PVC grew rapidly in the 1990s, reaching 14.4 billion pounds in the US and Canada in 2002.<sup>14</sup> This is equivalent to 46 pounds for every person in the two countries. PVC sales are much lower in other industrial countries: 31 pounds per person in Western

Europe, and 25 pounds per person in Japan.

Worldwide production was 59 billion pounds (or almost 27 million metric tons) in 2002, an average of 9 pounds per person. With 5 percent of the world's population, the US and Canada consume 24 percent of the world's PVC.

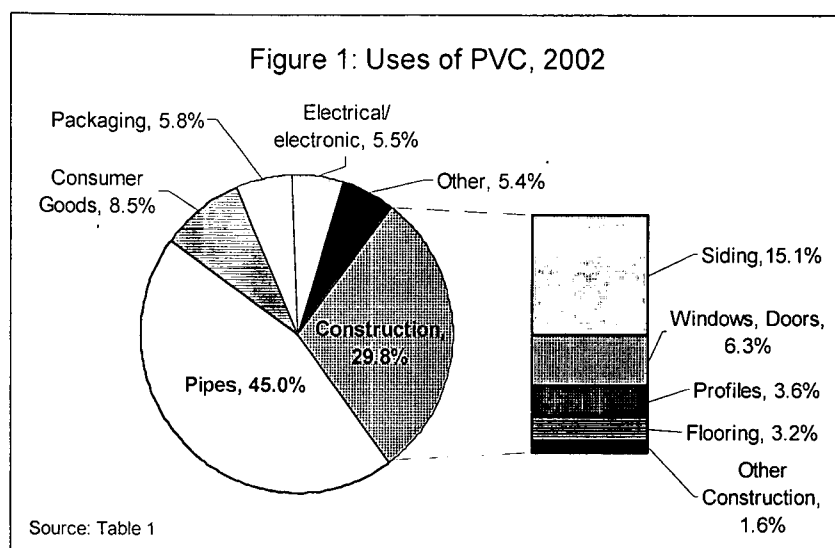
Data on the uses of PVC in the US and Canada for 1994, 1999, 2002, and forecasts for 2007, are shown in Table 1. The 2002 figures are also shown graphically in Figure 1. The principal uses of PVC, in order of importance, are pipes, construction materials, consumer goods, packaging, and electrical products such as wire and cable. Pipes, siding, windows, doors, and profiles (gutters, fences, decks, etc.) together account for more than two-thirds of PVC use, and are also the fastest-growing categories. Many other uses of PVC are growing more slowly, and a few actually declined in the recent economic slowdown. Industry projections for 2007 assume that the recession will end and growth will resume, although at a slower pace than in the 1990s.

**Table 1: PVC Consumption in US and Canada, 1994-2007**

End Uses	Consumption (millions of pounds)				Annual growth rates		
	1994	1999	2002	2007 est	94-99	99-02	02-07
Pipes, Tubing, Fittings	4,875	6,685	6,494	7,350	7%	-1%	3%
Construction	2,790	3,990	4,293	5,413	7%	2%	5%
Siding	1,470	2,175	2,176	2,710	8%	0%	4%
Windows and Doors	410	700	910	1,225	11%	9%	6%
Profiles	225	400	525	775	12%	9%	8%
Flooring	440	485	457	455	2%	-2%	0%
Roofing	115	100	100	113	-3%	0%	2%
Other Construction	130	130	125	135	0%	-1%	2%
Consumer Goods	915	1,225	1,225	1,225	6%	0%	0%
Packaging	820	885	839	935	2%	-2%	2%
Electrical / Electronic	540	870	800	905	10%	-3%	2%
Transportation	265	310	280	310	3%	-3%	2%
Home Furnishings	185	240	240	240	5%	0%	0%
Other and Inventory	337	128	259	325			
<b>Total</b>	<b>10,727</b>	<b>14,333</b>	<b>14,430</b>	<b>16,703</b>	<b>6.0%</b>	<b>0.2%</b>	<b>3.0%</b>

"Other and inventory" includes medical supplies (200 million pounds in 2002), coatings and adhesives (100 million pounds), and inventory changes for the industry as a whole, which can be positive or negative, and vary widely from year to year.

Source: SRI Consulting (Menlo Park, CA), CEH (Chemical Economics Handbook) Marketing Research Report: Polyvinyl Chloride (PVC) Resins (September, 2003).



### Costs of Replacing PVC: Three Studies

Three detailed studies, all published in the mid-1990s, have estimated the costs of phasing out PVC.

- The US-Canada International Joint Commission (IJC) for the Great Lakes examined the cost of phasing out PVC as part of its 1993 "Strategy for Virtual Elimination of Persistent Toxic Substances."<sup>15</sup> The report was done for the IJC by a Canadian consulting firm, Hickling Corporation. In 1994, Hickling submitted an expanded and revised version of its study.<sup>16</sup>
- In response to the IJC, the Chlorine Institute asked Charles River Associates (CRA), a US consulting firm, to study the economic benefits of chlorine and related chemicals, including an analysis of PVC.<sup>17</sup>
- In 1997, Environment Canada published a study of options for replacing chlorine-based products, including a detailed look at alternatives to PVC.<sup>18</sup>

These are the most extensive and comprehensive studies on the subject, although by now they are somewhat dated. Moreover, as we will explain, their cost estimates fail to incorporate several important factors that favor the adoption of alternatives. All three found PVC to be only modestly cheaper than the alternatives.

Each of the studies examined many specific uses of PVC, comparing the prices for PVC products to their PVC-free alternatives. Environment Canada created

two sets of price comparisons: a low case looking at the least expensive available alternatives, and a high case based on higher-priced alternative products that were in use in Canada.

Table 2 compares the results of the studies. For each study it shows the cost increase that would result from switching to PVC-free alternatives, expressed in dollars per pound of PVC (updated to 2002 prices). Cost estimates are shown separately for pipes and for all other products. Since pipes represent about half of all PVC use, the pipe and non-pipe figures in Table 2 are averaged to obtain a rough estimate of the total cost of replacing PVC.

**Table 2: Cost of Replacing PVC**

US dollars per pound of PVC (2002 prices)				
	CRA (industry)	Hickling (for IJC)	Environment Canada Low	High
Pipes	\$1.43	\$1.03	\$0.15	\$0.33
All other uses	\$0.87	\$1.10	\$0.94	\$3.84
Average	\$1.15	\$1.07	\$0.55	\$2.08

Average is the unweighted average of pipes and "all other uses" estimates  
Hickling data excludes windows

Table 2 shows a remarkable degree of agreement between the two earlier studies. With one minor adjustment to the Hickling data (incorporated in Table 2), the CRA and Hickling studies yield nearly identical average costs of replacing PVC—\$1.07 to \$1.15 per pound.<sup>19</sup> The Environment Canada low case had an average cost of about half this much, due to its much lower estimate for pipe costs. For the non-pipe uses of PVC, there is fairly close agreement

between CRA, Hickling, and the Environment Canada low case (\$0.87 to \$1.10 per pound).

The Environment Canada study, the most recent of the three, examined 14 product categories that accounted for about 90 percent of PVC use in Canada. In most categories, the study compared costs for PVC products, a common lower-priced

alternative, and a common higher-priced alternative (not necessarily the highest or lowest prices on the market). Published in 1997, the study is based on prices and conditions in Canada and construction costs for the Toronto area in 1993. Nine of the 14 product categories were in the areas of pipes and construction materials, as shown in Table 3.

**Table 3: Alternatives to PVC in Pipes and Construction**

Source: Environment Canada, 1997

End use	Alternative materials		Cost per pound of PVC replaced (US \$)	
	Low cost	High cost	Low cost	High cost
Municipal water pipe	HDPE	Ductile iron	\$0.26	\$0.38
Municipal sewer pipe	HDPE	Concrete		
Drainage pipe, culverts	HDPE	Concrete	(\$0.05)	\$0.25
Drain/waste/vent plumbing	ABS	ABS/Copper		
Industrial pipe, conduits	-----	HDPE -----		
Siding	Aluminum	Clay brick	\$0.38	\$6.02
Windows	Wood	Aluminum	(\$0.82)	\$0.38
Flooring	Polyolefin	Ceramic tile/carpet	\$13.54	\$17.07
Wire and cable	-----	Polyethylenes, other plastics -----	\$3.00	\$3.00

1993 Canadian prices converted to US dollars and adjusted for US inflation through 2002.  
 Separate low- and high-cost alternatives were not estimated for industrial pipe or for wire and cable.  
 Alternative materials reflect those in use in Canada in 1993, except polyolefin flooring (a polyethylene/polypropylene combination). This product was introduced in Germany in 1996; Environment Canada's low-cost flooring alternative uses the German price.

For pipes, the low-cost alternative to PVC was in each case another plastic, usually high-density polyethylene (HDPE). Traditional pipe materials such as iron, concrete, and copper provided slightly higher-cost alternatives. However, as shown in Table 3, the estimated price per pound of PVC replaced was small for all pipe applications and was actually negative (meaning the alternatives cost less than PVC) for low-cost drain and industrial applications.

The story is more complex for construction materials, where the available options are more diverse and are changing more rapidly than with pipes. For example, Environment Canada's low-cost siding alternative, aluminum siding, has all but disappeared from the market today. (Newer alternatives will be discussed below.) Flooring was the area with by far the highest cost; although it represented only 3 percent of all PVC use in Canada in 1993, it accounted for over half of the cost of the entire low-cost PVC replacement scenario. New flooring products have continued to appear, and some of the best alternatives today were not available at the time of the study.

Over all, the added costs of non-vinyl construction materials were modest: according to Environment Canada, the use of non-PVC alternatives for all four applications—siding, windows, flooring, and wire and cable—would have increased the cost of new residential construction by 0.4 percent in the low case, or 2.4 percent in the high case.

If these estimates applied today, what would they imply for the costs of phasing out PVC? As mentioned above, PVC consumption in 2002 was about 14.4 billion pounds for the US and Canada as a whole, or 46 pounds per person. The Environment Canada low case, the most recent and detailed cost analysis, suggests an average cost increase of \$0.55 per pound from switching to alternatives (see Table 2). If this figure still applied, the total cost for replacing all PVC use would be about \$8 billion a year for the US and Canada as a whole, or \$25 per person.

While it is based on the best available published figures, this calculation has limited applicability

today. Recall that over half of Environment Canada's total cost of alternatives came from a very high estimate for the cost of replacing vinyl flooring. As we will see, better alternatives are available today, with life-cycle costs lower than vinyl flooring. Remove the inflated flooring cost, and Environment

Canada's estimate shrinks to less than \$4 billion total, or \$12 per person. And this is not the only factor tending to lower the cost of alternatives. In the section that follows, we examine several reasons why the cost of a phaseout will probably be even lower than suggested by current prices.

## Factors Favoring Phaseout

Although the Environment Canada-based estimates of the costs of a phaseout are still too high, it is worth noting that they are not enormous compared to the North American economy. Affordable housing would not suddenly become unaffordable if, as Environment Canada estimated, replacing the leading uses of vinyl were to raise new residential construction costs by 0.4 percent (and this figure included the inflated flooring cost). Even \$8 billion is less than 0.1 percent of the gross domestic product of the US and Canada; with the correction for flooring, the revised \$4 billion cost is \$12 per capita, less than 0.05 percent of our collective incomes. A loss of this amount, spread across the entire economy, would not cause a noticeable average change in our lifestyles and consumption levels.

Moreover, the estimated cost differences, as described above, overstate the economic benefits of PVC. There are four economic arguments for elimination of PVC, despite its modest cost advantage in some settings at current prices.

### *Life-Cycle Costs Often Favor Alternatives*

Some of the alternatives have higher initial purchase prices than PVC products, but are actually less expensive over the useful life of the product. The three studies described above compared purchase prices, or in some cases installed costs, of PVC and alternatives. Such comparisons may give a misleading impression about the total cost of owning, using, and caring for the products in question.

The total cost over a product's life cycle is the cost that ultimately matters to the user. For example, paper plates are much cheaper than ceramic dinner plates, but households, restaurants, and institutional food services often conclude that it is cheaper in the long run to buy, wash, and reuse ceramic plates, rather than continually buying and discarding paper plates.

The concept of life-cycle costs is no more complicated than this familiar example. Rather than making a decision based on initial costs alone, it is important to compare the full costs, over a period of time, of buying, installing, using, maintaining, and ultimately disposing of alternative products. If a ceramic plate is used daily and is expected to last for a year, then the correct comparison would be the cost

of 1 purchase, 365 washings, and 1 disposal versus the cost of buying and disposing of 365 paper plates.<sup>20</sup> As in this case, a more expensive initial purchase may be cheaper in the long run if it lasts longer and/or requires less maintenance or fewer repairs.

For some building materials, such as flooring, maintenance and repair costs can be the largest costs of the product life cycle. In such cases, the lowest-maintenance product is often the cheapest on a life-cycle basis, regardless of whether it has the lowest purchase price. As we will see in a later section, vinyl is the cheapest option for commercial and institutional flooring on a first-cost basis but the most expensive option on a life-cycle basis. When life-cycle costs are taken into account, vinyl flooring loses out to higher-priced but longer-lasting and more easily maintained alternatives.

The discussion of life-cycle costs should not be confused with academic studies known as "life-cycle analyses" (LCAs). A life-cycle cost comparison looks at the costs to the user of a product from purchase through disposal. Life-cycle analysis, on the other hand, attempts to account for all the environmental impacts of a given product, from production through use and disposal. Depending on the data categories that are included, LCAs may provide useful environmental information, but they are not a substitute for a life-cycle cost comparison. Note that life-cycle costs do not directly depend on the environmental impacts included in a LCA; rather, life-cycle costs reflect durability and ease of maintenance, as well as initial costs.

Surprisingly, some LCAs have given PVC relatively good ratings. However, these LCAs often omit the highly toxic and carcinogenic emissions that are the most serious problems associated with PVC.<sup>21</sup> LCAs that include toxic emissions do identify PVC as an undesirable material. The Tellus Institute Packaging Study, an early LCA that evaluated common packaging materials primarily on the basis of life-cycle toxicity, found that PVC was 10 to 12 times worse than other common plastics (which include some of the leading alternatives to PVC). If the Tellus study had used the Vinyl Institute's own estimates of emissions, published at about the same time, instead of the best available public data sources, it would have found that PVC was "only" four times as bad as other plastics.<sup>22</sup>

### **Mass Production Reduces Costs**

Mass production makes everything cheaper. Many PVC products have been produced in huge volumes, making them look cheap today; the production of PVC alternatives could just as easily grow in volume in the future, making them less expensive and more competitive than they are at present. There are two related effects at work here, known as “economies of scale” and “learning curves.”

*Economies of scale* refer to the fact that production costs per unit are often lower when goods are produced in larger batches. There are several reasons why it is cheaper for a big factory to produce large amounts of a single product, compared to smaller plants producing lesser quantities of the same good. Some processes are physically more efficient when performed on a larger scale; a bigger boiler or furnace simply costs less to operate, per unit of heat output, than a small one. In general, a larger scale of production means that more machinery, automation, and standardized procedures can be applied. A company that sells a few hundred plastic objects of a particular shape each year may have workers make them almost by hand, using only basic tools and equipment. A company that sells a few million a year will invest in molding and stamping machines, assembly lines, etc., allowing much faster, labor-saving, lower-cost production.

*Learning curves* describe the common pattern in which costs decline over time as an industry gains experience with a production process. This is often combined with economies of scale—as industry gains experience, factories also tend to get bigger—but learning curves are possible even if factory sizes do not change. Whenever a new process is introduced, it takes a while to debug it; hence the common, informal advice to avoid version 1.0 of any new software package. Much the same is true for manufacturing. Over time, the bugs are worked out, shortcuts and process improvements are developed, and maintenance procedures and schedules are improved. As a result, costs go down. This phenomenon was first documented in the aircraft industry in the 1930s and has been observed in industries ranging from shipbuilding to wind turbines and photovoltaic cells.<sup>23</sup> A common estimate is that when an industry’s cumulative production (the total from the beginning of the industry to the present) doubles, the cost per unit drops by 10 percent to 30 percent. In one classic example, a study found that the Ford Model T dropped in price by 15 percent for

every doubling of cumulative production from 1909 to 1923.<sup>24</sup>

The combined effects of economies of scale and learning curves can be seen in the evolution of many consumer electronics products. Cell phones, CD players, DVD players, digital cameras, flat screen computer monitors, and numerous other products started out as expensive and esoteric luxuries and then dropped rapidly in price as the market expanded.

At a certain point, the fact that some people are using a new product means that other people will begin to use it too. For example, if many people have begun to use a new computer program, other people will adopt it simply in order to have a system compatible with that of their colleagues. Conversely, it might be inconvenient to be the only person in a city with an unusual car model, because repairs would be expensive and parts would be hard to find. Thus, for a new technology, the fact that some people have already adopted it eventually becomes a strong argument for further adoptions. By pushing up demand, this pattern creates a snowballing effect that lowers prices and tends to “lock in” the advantage of the product that currently leads the market.<sup>25</sup>

Thus, when a product sells for a relatively low price and is used widely, we cannot assume that it is used widely simply *because* it is cheap. It may, instead, be cheap because it is used widely.

PVC has benefited from mass production in many markets. PVC products have been used for decades, have achieved large sales volume, and thus are mass-produced at low cost. The learning curve effect appears to have been particularly steep for PVC, with every doubling of production associated with a 30 percent to 40 percent drop in price in the 1950s and 1960s.<sup>26</sup> A history of the industry describes a steady stream of process innovations and improvements in production technology in these early years, along with rapid increases in the size of the newest and most efficient plants; these factors undoubtedly drove the price downward.<sup>27</sup>

Many of the less toxic alternatives are not yet firmly established in the market; they do not currently enjoy economies of scale and learning curve advantages comparable to those enjoyed by PVC. In some cases, less toxic alternatives that were once popular may have benefited from economies of scale in the past but have been pushed aside by vinyl and are now produced in relatively small quantities. Linoleum flooring and aluminum siding are examples of this pattern. Analyses of the long-run costs of a PVC-free

future should look beyond the current price of alternative products to their (likely lower) future price as they become widely adopted and mass-produced.

### *PVC Products Can Be Dangerous to Users*

Often the harmful effects of PVC emerge during the intended use of the product. For example, flexible PVC products used in health care, such as IV bags and tubes, contain phthalates—plasticizers that can leach out of the products during use, posing hazards to patients.<sup>28</sup> The US Food and Drug Administration has issued an advisory, for example, recommending measures to reduce patients' exposure to the phthalate Di(2-ethylhexyl)phthalate (DEHP) in medical devices.<sup>29</sup> Phthalates are also used in some flexible PVC toys, including toys that young children are likely to put in their mouths. In 1999, the European Commission adopted an emergency ban on certain phthalate-containing PVC toys and other products, such as teething rings, intended for children to put in their mouths. This ban has been renewed repeatedly, pending development of permanent regulations. Some, though not all, US manufacturers have voluntarily stopped production of PVC toys containing phthalates.<sup>30</sup> (The US Consumer Product Safety Commission has denied petitions to ban PVC in toys for young children or to issue an advisory about hazards associated with these toys.<sup>31</sup>)

Additional problems occur when PVC is exposed, intentionally or otherwise, to heat. In case of fire, vinyl building products release large quantities of hydrochloric acid, and smaller quantities of many other toxins, threatening building occupants and neighbors as well as firefighters. For this reason, some firefighter associations are working to educate the public about the hazards of PVC and are supporting municipal and state level policies to reduce PVC use. The International Association of Fire Fighters points out that 165 people died in the Beverly Hills Supper Club Fire of 1977, and 85 people in the MGM Grand Hotel Fire in Las Vegas in 1980—almost all of whom, according to the firefighters, were killed by inhalation of toxic fumes and gases, not by heat, flames, or carbon dioxide. A likely culprit is the hydrochloric acid created by the decomposition of PVC used in wiring and other building materials.<sup>32</sup> Medical researchers have found elevated levels of long-term respiratory and other health problems in firefighters who put out fires involving large quantities of PVC and have identified hydrochloric acid—acting alone or in combination

with carbon monoxide and soot—as the probable cause of the damages.<sup>33</sup>

PVC is often advertised as “fire resistant,” meaning that a fairly high temperature is required to start it burning. However, PVC starts to smolder and release toxic fumes such as hydrochloric acid at a lower temperature, long before it ignites. If PVC is gradually warmed, more than half of its weight is given off as fumes before it gets hot enough to burst into flames.<sup>34</sup> The hydrochloric acid released by burning PVC is potentially lethal to people caught in a burning building; other products of PVC combustion, such as dioxin, exert their health effects more slowly and are spread across a larger population.

Related hazards occur with PVC-insulated wiring, which was once standard for use in airplanes. There is no proof that PVC insulation has ever caused a plane crash, but some investigators have suggested that there are grounds for concern about older planes that still contain PVC-insulated wires. Full-sized modern airplanes contain 100 or more *miles* of wiring. The insulation on this wiring is critical to air safety: defects in the insulation could allow short circuits and sparks, potentially setting off a fire or explosion. A possible example is ValuJet Flight 592, a DC-9 that crashed in 1996, killing all 110 people on board. Although the flight crew reported an electrical power failure moments before the aircraft crashed, many reports instead focused on the possibility that oxygen tanks on board caused the crash. *Aviation Today* said in a special report on this and another accident,

The ValuJet Flight 592 accident aircraft was rigged with a type of wire insulation, PVC, that will not pass the FAA's current flame test.... Among PVC wire's unacceptable properties, its burning insulation creates copious amounts of smoke, and the insulation can turn to hydrochloric acid when exposed to moisture. It is found on all DC-9s built through 1975. In addition, the vast majority of 727s...were built with PVC wire. According to an anonymous telephone call to investigators from a self-described company maintenance technician three days after the ValuJet crash, the accident aircraft "was continually having electrical problems...circuit breakers and wiring were shorting out..."<sup>35</sup>

Use of PVC wiring is now prohibited on new planes, since PVC insulation failed Federal Aviation Administration (FAA) flammability tests in 1972.<sup>36</sup>



But as *Aviation Today* noted, many older airplanes that are still flying contain PVC-coated wiring; the FAA never banned its use.<sup>37</sup> The US Air Force discontinued installation of PVC in 1977, although replacing all of the existing wiring at once was too expensive; the schedule for gradual replacement of wiring in some Air Force planes stretches out until 2015.<sup>38</sup> Meanwhile, the potential hazards of older planes continue: there have been at least nine instances of in-flight electrical fires in DC-9 aircraft since 1983, three of which occurred after the ValuJet crash.<sup>39</sup>

In these and similar cases, PVC is an inferior product precisely because of its health and environmental hazards, for those who use it as well as those who make it.

### ***Environmental Protection Costs Less Than Anticipated***

The costs of environmental protection are often overestimated in advance. One of the classic examples of this trend actually occurred in PVC production. A strict standard for workplace exposure to vinyl chloride (the raw material from which PVC is made) was established in 1974 by the Occupational Safety and Health Administration (OSHA), following recognition of the likely carcinogenicity of vinyl chloride. Consultants to OSHA estimated the costs of reducing vinyl chloride exposure at around \$1 billion; industry estimates were even higher. Actual costs turned out to be around a quarter of OSHA's estimate, since industry quickly developed new, cost-effective technologies to comply with the regulation.<sup>40</sup>

Similar patterns have been found for many environmental standards. One study found that compliance costs for environmental regulations were overestimated in advance in 11 out of 12 cases. Another study found that advance cost estimates for environmental compliance turned out to be more than 25 percent too high in 14 out of 28 cases, while they were more than 25 percent too low in only 3 of the 28 cases.<sup>41</sup> A review of this literature for Environment Canada and the Ontario Ministry of Energy, Science and Technology, focusing specifically on the costs of controlling chlorinated substances, confirmed that overestimation of regulatory costs is more common than underestimation. Among the cases where it found serious overestimation of US regulatory costs were the advance predictions of compliance costs for the Montreal Protocol on ozone-depleting substances

and the bans on the toxic pesticides DDT and chlordane/heptachlor.<sup>42</sup>

There are at least three reasons for this repeatedly lighter-than-expected burden. First, economies of scale and learning curve effects are usually not built into prospective cost estimates, but often arise in the production of pollution control devices and cleaner alternative materials. Second, as with vinyl chloride, regulation may stimulate innovation and lead to the introduction of new, more efficient technologies. Finally, overestimation of costs may at times be a bargaining tactic for industry in arguing against environmental protection.

While many of the analyses cited here refer to regulations, often involving traditional end-of-pipe pollution controls, exactly the same factors are at work in the case of clean production alternatives: economies of scale and learning curves will be important, industry will develop new technologies to ease the transition, and the costs of the transition to clean production may be exaggerated in advance for rhetorical or bargaining purposes.

The best-known claims of extraordinary costs imposed by environmental policy do not stand up to careful examination; they turn out to be based on a series of errors and misinterpretations.<sup>43</sup> This has important implications for employment and other economic impacts. Despite rhetorical claims to the contrary, environmental protection has almost never caused noticeable numbers of job losses.<sup>44</sup> Moreover, the critics often forget that environmental initiatives create jobs, many of them skilled blue-collar jobs. The phaseout of PVC is a case in point; the alternatives to PVC are guaranteed to require the efforts of industrial and construction workers. The possible employment implications of a PVC phaseout are examined in a later section of this report.

## Markets for Alternatives

Because the uses of PVC are so diverse, the alternatives are likewise varied. The next five sections look at specific markets for PVC, exploring the available alternatives, the different properties that make alternatives more or less attractive, and the costs of replacing PVC with safer products. The first three markets involve products used in commercial

and institutional construction: pipes, roofing, and flooring.<sup>45</sup> The fourth examines medical supplies, particularly gloves. Finally, we take a brief look at the fast-growing residential construction uses of vinyl in siding and windows.

### *Alternatives to PVC, I: Pipes*<sup>46</sup>

Much of the PVC used is invisible to most of us; it is usually buried underground—or under the sink or behind the walls. But visible or not, modern life involves a lot of pipes. Some estimates suggest that municipal water and sewer systems will acquire \$8 billion of pipes annually for the next 20 years. In addition, large quantities of pipes will be installed to meet residential, commercial, industrial, and agricultural needs. Many of these pipes will be made of PVC, providing by far the most important market for vinyl. Pipes and pipe fittings make up almost half of PVC use, as seen in Table 1.

PVC pipes have been in use for at least 30 years and have become standard in some applications, such as the “drain/waste/vent” (DWV) tubing that carries wastewater away from kitchens and bathrooms. They have also gained a large share of the market for small-diameter municipal water and sewer pipes and for electrical conduits. According to industry estimates, on a lineal basis PVC accounts for more than 70 percent of all water and sewer pipes now being installed in the US.<sup>47</sup>

PVC pipes are competing both with traditional pipe materials—copper, iron, concrete, and vitrified clay—and with polyethylene (PE) and other plastic pipes. Among other plastics, acrylonitrile butadiene styrene (ABS) is sometimes used for drain pipes; however, PE is by far the most important plastic pipe material after PVC. The different pipe materials have contrasting strengths and weaknesses.<sup>48</sup>

- The traditional materials are heavier and, for large-diameter pipes, may be harder to install and repair. However, they are strong under extremes of pressure and temperature. Copper plumbing remains the standard for hot and cold water in most buildings. Iron water and sewer pipes may corrode in acidic

soil; they are sometimes coated with tar to combat corrosion.

- PVC is lightweight and lower priced than some alternatives and requires less skill to install and repair. However, PVC is weaker under high pressure and becomes brittle at below-freezing temperatures. For hot water pipes, a more expensive, modified form, chlorinated PVC (CPVC), must be used.
- PE pipes offer a lightweight alternative with greater strength under pressure, as well as stronger, more leak-proof joints and the ability to withstand temperatures well below freezing. For hot water pipes, a more expensive, modified form, cross-linked polyethylene (XLPE, marketed as PEX), must be used.

In view of its emerging role as an alternative to PVC pipes, we begin with an examination of the PE pipe industry. We then discuss the two major market segments: municipal water and sewer pipes and plumbing within buildings, including a detailed look at a recently constructed building that specified PVC-free plumbing. We conclude with price comparisons for several common plumbing jobs with and without PVC.

### **Polyethylene Pipe**<sup>49</sup>

PE pipes are one of the most important alternatives to PVC. PE is the only other leading material to approach PVC in both weight and ease of installation; while some equipment is needed to install PE pipes, small-scale pipe-welding machines are becoming available for homeowner or small contractor use. Moreover, PE has important advantages over PVC, such as greater strength under pressure and under low temperatures, and lower rates of leaks and breakage. Production of polyethylene, although not pollution-free, is far less toxic than

production of PVC; most of the toxic effects of the PVC life cycle involve chlorinated emissions, and PE does not contain chlorine.

PEX (cross-linked polyethylene) is suitable for hot and cold water and, because of its flexibility, can easily be bent around corners without a coupling or fitting, reducing labor time and the potential for leaks and system failures that tend to occur at joints in fittings. Because of its inherent flexibility, it has high tolerance for expansion and contraction, thus making it burst resistant.

Sales of PE pipe in the US and Canada, as estimated by the Plastics Pipe Institute, have grown rapidly, doubling in just a few years in the late 1990s.<sup>50</sup> PE pipe sales for 2000 and 2001 are shown in Table 4. The total reached 1.4 billion pounds in 2000, before dropping back to a little over 1.0 billion pounds as the economy slumped in 2001. For comparison, PVC pipe sales are around 6.5 billion pounds a year, as shown in Table 1.

Small declines in PE pipe sales occurred in many areas in 2001, reflecting the economic slowdown and reduced pace of construction. The largest decline occurred in conduits, which represented one-third of all PE pipe sold in 2000. PE conduits were widely used in the "dot-com" economy with its many cable and conduit needs; this market suffered an abrupt downturn beginning in 2001.

Substantial quantities of PE pipe are used in areas that do not compete with PVC, such as gas distribution and oil and gas production. Water and sewer pipes, which are areas of direct competition between the two plastics, are among the top uses for PVC, but represent only a fraction of the PE pipe market.

Some companies produce both PE and PVC pipe, giving them an additional motive to avoid competition between rival plastics. For example, J-M Manufacturing, the world's largest PVC pipe manufacturer, recently acquired Quail, an Arkansas-based manufacturer of PE piping. J-M acknowledges an increased demand for PE, attributable in part to the appeal of leak-free joints as well as contractors' increased familiarity and ability to work with the material.<sup>51</sup> They also are projecting increased market demand for PE in the water/sewer markets, in addition to the strong hold that PE currently has in the gas market.

**Table 4: Markets for Polyethylene Pipe**

	millions of pounds sold in US and Canada	
	2000	2001
<b>Uses competing with PVC</b>		
Water pipes		
Potable water up to 3"	77	75
Potable water 4" and above	65	58
Irrigation and agriculture	38	37
Sewers and drains	42	46
Conduits	500	193
Industrial and mining	178	174
Landfills	11	14
Crosslinked (PEX) pipe	20	32
<b>Subtotal, competing with PVC</b>	<b>931</b>	<b>629</b>
<b>Other uses</b>		
Gas distribution	236	210
Oil and gas production	180	180
Other	33	39
Export	36	15
<b>Subtotal, other uses</b>	<b>485</b>	<b>444</b>
<b>Total</b>	<b>1416</b>	<b>1073</b>

Source: Plastics Pipe Institute, "2001 Statistics: North American Shipments of Polyethylene & Crosslinked Polyethylene Pipe, Tube & Conduit"

PE pipe is newer to the market and hence less familiar to plumbers, contractors, and municipal public works departments, than PVC and traditional pipe materials. The American Water Works Association first gave its approval for the use of small-diameter PE water pipes in 1978, and for larger diameters only in 1990. PE plumbing has also been approved by the National Sanitation Foundation.

Reluctance to embrace new materials, including CPVC, PEX, and PE, especially in large commercial projects, results in part from memories of the failure of an earlier "new" pipe material, polybutylene (PB). Introduced in the late 1970s, PB pipe quickly gained a reputation for frequent leaks. However, it continued to be sold through the 1980s and early 1990s because its ease of installation allowed savings of hundreds of dollars per home. A class action suit against Shell, the largest manufacturer of PB pipe, *Cox v. Shell*, was settled in 1995 for \$950 million, one of the largest settlements in US history.<sup>52</sup> Today, numerous companies offer PB pipe removal services.

### Water and Sewer Pipes

PVC has been very successful in the market for small-diameter municipal water and sewer pipes. Some observers claim that PVC pipe installation minimizes municipal labor and equipment costs and also minimizes the length of time that streets are blocked for pipe installation. For larger diameter main pipes, where strength under pressure is of great concern, the traditional materials have retained a substantial share of the market, and PE is a stronger contender than PVC. Strength under extreme temperatures is more important in northern areas where the ground often freezes; accordingly, PVC has made greater inroads in southern, frost-free parts of the country.

Not everyone, however, has opted for PVC. In recent years, some municipal water and sewer systems have chosen PE instead of PVC. Performance issues, not cost, appear to drive the decision. The Indianapolis Water Company (IWC) has switched to PE because it reduces leaks at the joints and bends in the pipes and because a new installation technique (which works only with PE) minimizes excavation and disruption. IWC has now installed more than 30 miles of PE pipe of diameters larger than 20 inches.<sup>53</sup>

IWC is a subsidiary of United Water Company, a large private company that operates privatized water systems in many areas. United Water affiliates in New Jersey and New York also choose to avoid PVC in order to minimize leaks, since they operate in congested urban areas where it is expensive and difficult to excavate and repair underground pipes. Local building codes and conditions require very strong pipes, and United Water uses iron and cement pipes in New York and New Jersey; PVC is not durable enough for use under these conditions. However, United Water does use some PVC in Florida, where there is less concern about damage to pipes due to frost.<sup>54</sup>

California communities that have switched to PE or other non-PVC pipes for some applications include the Contra Costa Public Works Department, which uses PE pipes for storm drains; they view PE as superior to concrete or metal pipe on the basis of its low weight, ease of installation, low cost, and reduced level of leaks at the joints. The Los Angeles Department of Water and Power has used PE pipes to replace old water mains after major breaks, because it is the material that minimizes leaks.

PE pipe producers have described additional case studies of adoption of PE pipe for water distribution

systems in Palermo, Italy, and in Toronto, as well as in smaller communities throughout the US.<sup>55</sup> In these cases, PE was selected for characteristics including resistance to earthquakes and freezing, minimal damage to sensitive environments (the flexibility of PE allows less invasive drilling techniques for laying pipe), and the long-term integrity of its heat-fused joints.

Municipal agencies and decision-makers rarely view the price of the pipes themselves as the most important factor in choosing water and sewer pipes. A representative of the Boston Water and Sewer Commission emphasized this point, stating that it costs so much to dig up the streets and install the pipes that the price of the pipe itself is irrelevant to the city's decision. Boston uses the pipe material that the agency considers appropriate to each job: ductile iron for water mains; copper for house services; ductile iron or reinforced concrete for large diameter sewer pipes; and PVC for small diameter sewer pipes. PVC was chosen for the smaller sewer pipes on the basis of its light weight and ease of connection.<sup>56</sup>

PVC has also been adopted for other low-pressure, low-temperature-stress applications such as irrigation pipes, culverts, drain pipes, and some industrial pipes. However, high-pressure applications, such as gas pipelines, cannot use PVC; instead, PE pipe has a major share of these markets.

If hydrogen becomes an important fuel in the future, as the Bush administration and others have sometimes suggested, a system of non-PVC pipes will be needed to transport it: hydrogen can diffuse out through the walls of PVC pipes, due to the porous molecular structure of the PVC polymer. (PE, although not as porous as PVC, apparently is also unsuitable for hydrogen pipelines.)<sup>57</sup>

In short, despite PVC's continuing strength in this major market, there are other materials that play an important role, and numerous municipal customers who have decided to rely on alternatives to PVC for some or all of their pipe needs.

### PVC Plumbing and Conduits: Pro and Con

Different considerations arise in plumbing, as well as conduits for wire and cable, within buildings. For do-it-yourself plumbing, sections of small-diameter PVC pipe, manufactured in 10-foot or 20-foot lengths, are easy to cut to the desired length and join together with pipe cement (although some pipe cement products used in home plumbing are themselves

toxic<sup>58</sup>). However, when plumbing is installed by skilled workers, PVC loses this advantage: it requires more joints, and time must be spent waiting for cemented joints to dry before testing and using the pipes, in contrast to alternatives with fewer, but stronger, welded joints.

For electrical conduits, PVC competes with steel; steel is more expensive and harder to bend and install, but is often required by building codes for its much greater fire resistance. PVC is of course more flammable than steel, but it is also less flammable than other plastics. For conduits where fire resistance is less of a concern, such as optical fiber and computer network cables, PE has been widely adopted.

Outstanding concerns regarding fire hazards have driven building codes in some areas, such as the city of Chicago, to exclude all plastic piping, including PVC and CPVC, from all commercial building applications. Chicago also prohibits plastic pipe in all residential structures three stories and above. New York State has similar legislation, banning plastic pipe, including PVC, from all commercial buildings and from residential buildings over six stories in height, at least through 2004. Industry critics attack such measures as make-work regulations that needlessly drive up construction costs in order to protect union jobs. Unions defend them as safety measures, citing the health hazards of PVC fires.<sup>59</sup>

Both the Chicago and the New York State standards apply to all plastic pipes, not just PVC. Some supporters of these standards have argued that all plastic pipes are flammable and will ignite at lower temperatures than other building materials. This remains a controversial view; many critics have rejected the idea that the use of plastic pipes affects the risk of fire.<sup>60</sup>

Even where PVC pipe is allowed by building codes, concerns about fire prevention may raise its effective cost. Based on experience in the design of an eight-story residential assisted living facility in Cambridge, Massachusetts, engineering consultant John Rattenbury concludes that the cost advantage of PVC over cast iron plumbing is largely illusory. Although the price per foot for sanitary and storm drains appears to be at least three times as high for cast iron pipes as for PVC, the building code requires firestopping protection every time PVC passes through a wall, plus thermal expansion joints on PVC pipes. Iron is completely fireproof and has a much lower coefficient of thermal expansion, so the requirements are much less taxing for iron pipes.

These and other difficulties make installation in a multi-story building far more expensive with PVC, offsetting most of the apparent cost advantage. In addition, Rattenbury observes that cast iron drain pipes are much quieter.<sup>61</sup>

### **Case Study: Building Without PVC Pipes<sup>62</sup>**

Although PVC has become conventional for some plumbing uses, large commercial and residential buildings can be built with no PVC pipes. There are examples of such buildings around the country. In some cases PVC must be avoided due to building codes, as in Chicago and New York; in other cases the choice of PVC-free plumbing is due to the growing interest in "green building" design in general and the desire to minimize PVC use in particular.

One such building is the Austin Resource Center for the Homeless in Austin, Texas. (It is far from the only example, even in Texas: the University of Texas-Houston School of Nursing building made almost identical choices about pipes.) This project, located in downtown Austin, is a 26,820 gross square foot building with a construction budget of \$4.7 million. For this project, copper was specified as the domestic water piping, and cast iron was used in all other interior pipe applications, with polyethylene used for irrigation pipe. According to the plumbing contractor, MJ Mechanical, these pipe choices resulted in an estimated 15 percent total increase in the costs of plumbing materials and labor.

- The decision to choose copper over PVC for domestic water arose independently of the project goal; in general, copper is a common choice for domestic water pipes. Copper provides long-term reliability and familiarity, which are important for both owners and the trades.<sup>63</sup> The PVC option for hot water pipes would require CPVC (chlorinated polyvinyl chloride), formulated to withstand higher temperatures than standard PVC. (At this point, CPVC is still considered a new market entry, with only a 10 to 15 year track record in the US. For experienced installers, copper can be installed in about the same time as PVC; industry handbooks estimate that it costs 10 percent more to install CPVC than to install copper.)
- For sanitary, waste, and vent pipes, cast iron was used instead of PVC even though PVC has become the standard material for these applications. The cast iron cost 15 percent more than PVC for materials, and did not change labor costs.
- To water the grounds, the project specifications called for flexible polyethylene pipe housed in

steel sleeves. The specification of the steel sleeves was based on concerns that the PE pipe could become brittle and thus require additional protection. This boosts both the material and labor costs of this system; installation labor expenses are estimated to run about three times the cost of installing PVC irrigation pipe without a sleeve. However, some pipe experts believe that such sleeves are unnecessary on PE pipes and would describe this as a case where misconceptions about materials led to more costly choices.<sup>64</sup>

### Plumbing Price Comparisons

To conclude our discussion of pipes, we look at the costs of PVC and alternatives for several categories of plumbing. Table 5 shows the retail purchase price for two varieties of small-diameter pipes: 3/4-inch pipes made of materials not suited for hot water, and 1/2-inch pipes that are able to carry hot water. Note that PVC and PE are fairly close in price for 3/4-inch pipe, as are CPVC and PEX for 1/2-inch hot/cold water pipe. Only copper is distinctly more expensive among the alternatives shown in Table 5.

Table 5: Retail Plumbing Prices		
Category	Material	Price per foot
3/4-inch pipe	PVC	\$0.14
	PE	\$0.16
1/2-inch	CPVC	\$0.29
	PEX	\$0.34
hot/cold water pipe	hard copper	\$0.58
	soft copper	\$0.67

PVC is Schedule 40; copper is Type L. Prices are for various lengths (10 - 100 feet), converted to price per foot.

Prices are from Home Depot and Lowe's on line, and from an Austin, Texas, plumbing supply store, as of September 2003.

The small differences in material price between PVC and PE plumbing, seen in Table 5, are rarely decisive for the total cost of a plumbing job. Tables 6 and 7 present installation costs for 3/4-inch plumbing, based on a standard database that is widely used in the industry for estimating job costs. Table 6 presents the costs for pipe installation alone, showing that installation of PE-aluminum, or PEX-aluminum, pipe is cheaper than CPVC. Labor costs are much greater than material costs and vary more widely between the two jobs: differing labor costs account for almost all of the difference in total cost between CPVC and the PE options.

**Table 6: Installation Costs, 3/4-inch Plumbing - Pipe Only**

	(amount per lineal foot)			
	Labor Hours	Labor Cost	Material Cost	Total Cost
CPVC	0.055	\$1.51	\$0.55	\$2.06
Cross linked PE-aluminum	0.030	\$0.83	\$0.60	\$1.43
PE-aluminum	0.030	\$0.83	\$0.47	\$1.30

CPVC has solvent welded joints; both PE-aluminum pipes have crimped joints.

Source: 2003 National Plumbing & HVAC Estimator

Table 7 presents an expanded estimate of installation costs, including the hangers and tees required by plumbing codes as well as the pipe itself. Note that the two tables refer to different categories of pipe: Table 6 refers to hot/cold water pipe, whereas Table 7 does not. In the latter case, the comparison shows that PVC is somewhat cheaper than copper, again almost entirely due to differences in labor requirements.

**Table 7: Installation Costs, 3/4-inch Plumbing - Complete Installation**

	(amount per lineal foot)			
	Labor Hours	Labor Cost	Material Cost	Total Cost
Copper	0.116	\$3.20	\$0.76	\$3.97
PVC	0.091	\$2.52	\$0.72	\$3.24

Complete installation includes hangers and tees, as required by code.

Copper is Type L, with brazed joints, installed horizontally.

PVC is Schedule 40 with solvent-weld joints, installed horizontally.

Source: 2003 National Plumbing & HVAC Estimator

For small-diameter plumbing, the price comparisons do not tell a story of large advantage in either direction: retail prices are similar for PVC and other plumbing materials (Table 5); installation cost estimates favor the alternatives in some cases (Table 6) and PVC in others (Table 7). It seems safe to conclude that there are feasible, affordable alternatives for PVC-free plumbing.

### Alternatives to PVC, II: Roofing

Roofing is a \$30 billion-a-year industry that installs new and replacement roofs made from a wide range of materials.<sup>65</sup> Although multi-ply (multi-layer) roofs can be applied on any building, it is increasingly common to use single-ply roofing membranes, particularly in low-slope applications for commercial buildings. To provide for a range of different uses, single-ply roofing membrane manufacturers produce an extensive selection of membranes with varying levels of thickness and reinforcement.

There are three major single-ply roofing membrane materials for low-slope roofs: ethylene propylene diene monomer (EPDM), thermoplastic elastomer polyolefin (TPO), and PVC. (In steep-slope roofs, PVC has a market share of less than 0.5 percent.) The installed cost for any of the three is often cheaper than for other styles of roofing. As shown in Table 8, EPDM is clearly the market leader; the combination of EPDM, TPO, and PVC roofs together accounts for more than one-third of low-slope roofing sales. (Additional single-ply materials, included in "all other," amount to another 2 percent of sales.) Among single-ply roofing choices, the alternatives are often lower-priced than vinyl, as explained below.

Table 8: Low-slope roofing sales, 2002	
EPDM	23.7 %
Bitumen	22.4
Asphalt - built-up	16.6
Asphalt shingles	7.4
TPO	5.8
Metal	5.6
PVC	4.8
All other	13.7
<b>Total</b>	<b>100.0</b>
Low-slope roofs are those with a slope of less than 14 degrees.	
Figures are weighted averages of new roofs (29%) and re-roofing (71%), reflecting the relative proportion of sales.	
Source: Beverly Siegel, "An Industry Overview," <i>Professional Roofing Magazine</i> (April, 2003).	

#### Life-Cycle Roofing Costs

For roofing, as for other construction products, what matters for cost-effectiveness is the total life-cycle

cost of a product, rather than just its initial installed cost. On the Tufts University campus, for instance,

there are dozens of buildings that periodically require re-roofing. According to a general contractor that frequently works for the university, Tufts formerly used EPDM, but has now switched to built-up asphalt for low-slope roofs. Although the multi-layer asphalt roof costs almost twice as much per square foot as EPDM, Tufts has decided that the multi-layer roof is better suited to its requirements and reduces maintenance costs. PVC is not a viable option for the university, in the contractor's view, since it would cost even more per square foot than asphalt, due to the time-consuming installation process. In addition, it would not last as long and would tend to develop cracks and leaks.<sup>66</sup>

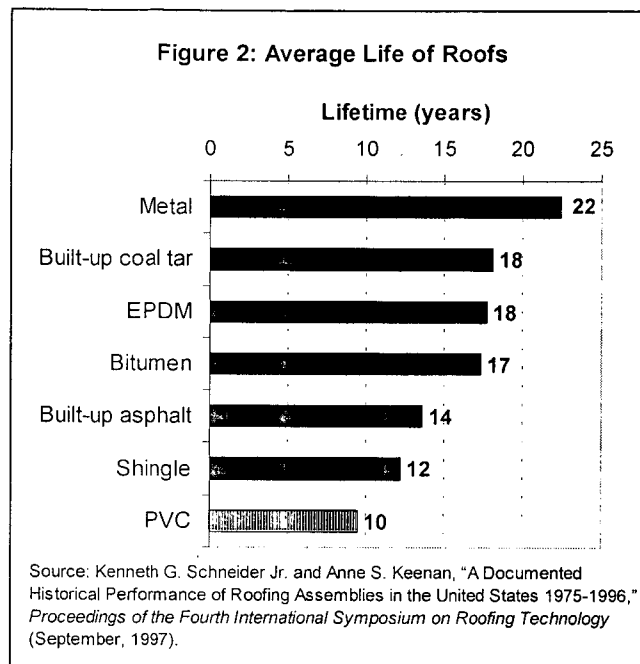
As this example suggests, the expected lifetime of a roof is crucial to its life-cycle costs. PVC does poorly by this standard. A study of the lifetimes of almost 24,000 low-slope roofs found that PVC had the shortest average life among the roofing types in the study (Figure 2). Thus, even if PVC and another roofing material had identical installed costs, PVC would have a higher cost per year of expected lifetime.<sup>67</sup>

#### Characteristics of Roofing Materials

As in other uses, the choice between PVC and rival roofing materials depends on the physical characteristics of the materials as well as the price differentials. Single-ply roofing systems are popular because of their comparatively low cost and ease of installation. Within the single-ply category, the leading materials are often seen as differing in reflectivity, energy efficiency, durability and flexibility, among other properties. In this section we discuss differences among PVC, EPDM, and TPO.

#### Reflectivity

The vinyl industry advertises the fact that white vinyl roofs reflect sunlight and thereby lower building temperatures, increasing the energy efficiency of a building when air conditioning is in use. This benefit has been recognized by EPA's Energy Star program, which identifies proven energy-conserving technologies. Until TPO was introduced, PVC was the only white, single-ply membrane roofing material available.



Today, however, there are other options for white roofs. TPO, a relatively new polymer, is available in white, tan, or gray. It was first introduced in 1991 in Europe and has since made the jump to the North American market, where it is gaining market share. EPDM, an inexpensive synthetic rubber product, is naturally black; however, it can be made white through coating or painting with a titanium dioxide layer. The New Orleans Superdome, for example, has a white EPDM roof.

During hot weather, roofing color is an important factor affecting energy efficiency. While the significance of white roofs is unquestioned for many parts of the country, there is an ongoing debate about the impact of roof color in northern climates. Buildings in northern climates often experience more heating than cooling days; some experts argue that this makes a solar-absorptive or darker colored roof preferable. Opponents of this view argue that white roofing reduces energy *costs* even in northern latitudes because cooling is a more expensive process than heating, due to its reliance on electricity rather than oil or natural gas. In addition, some roofs in northern climates are snow covered during much of the cold season, making the color of roofing materials less important during the winter.<sup>68</sup> Ongoing research on roof reflectivity at Oak Ridge National Laboratory will address this question; in a preliminary discussion of the research, the lead investigator suggested that

roof color might have little overall effect on building energy costs in northern climates.<sup>69</sup>

#### *Durability and Flexibility*

The three single-ply materials differ in durability and flexibility, with PVC generally lagging behind both of the other options.

Advantages of TPO membranes compared with PVC include superior flexibility in cold weather—allowing easier installation in cold climates<sup>70</sup>—and retention of flexibility throughout the life span of the material. EPDM offers similar advantages—the ability to withstanding a broad range of temperatures, resist weathering, and stretch and conform to unusual shapes. It has excellent UV radiation, ozone, and weathering resistance. In the past, a key disadvantage of EPDM was that its seams were less effective than those of either PVC or TPO under similar installation conditions. According to individuals working in the roofing industry, this problem has been eliminated with the advent of new seaming techniques using tape.

As in other vinyl products, additives such as plasticizers must be present in PVC roofing membranes in order for them to withstand frequent traffic and maintain flexibility. Gradual migration of plasticizers out of PVC roofing materials can lead to seam failure and structural damage, which were



problematic when PVC was first introduced to the roofing market. Stabilizers are now added to the PVC to slow migration of the plasticizers, increasing the life span of the PVC membrane, but this does not entirely eliminate the problem.

The shorter lifetime of PVC roofs, as shown in Figure 2, results in part from their tendency to become brittle and crack. This effect was highlighted in research by the US Army's Construction Engineering Research Laboratory (CERL). Launching a long-term investigation into PVC membrane roofing, a 1981 CERL report noted anecdotal evidence of PVC roof failures in both Switzerland and the United States, and said, "The two most serious PVC membrane problems are embrittlement from loss of plasticizer or from exposure to ultraviolet rays and excessive shrinkage."<sup>71</sup> A 1997 paper, reporting on CERL's ten-year field study of three PVC roofs at military installations, found that the performance of two of the roofs was "generally satisfactory," whereas "problems related to shattering and splitting" occurred at the third.<sup>72</sup> The paper offered a detailed technical comparison of samples of the three roofs, noting some evidence that the roof that shattered may have lost more plasticizer than the ones that remained intact.

### Methods of installation

The installed cost of a roof depends on the method of installation as well as the choice of material. There are three primary ways to install single-ply roofing systems: fully adhered, mechanically fastened, and ballasted. TPO, EPDM, and PVC can each be installed in any of these three ways.

A *fully adhered* roofing system uses the most expensive and labor-intensive method of installation. During installation of a fully adhered roofing system, insulation boards are placed first and fastened to an underlayment. This is a high performance system used in situations where leaks cannot be tolerated even temporarily, or where the roofing system may be exposed to high winds. Seams can also be heat-welded in a fully adhered roofing system.

A *mechanically fastened* roofing system is essentially a quicker, somewhat less thorough and less expensive variant on the fully adhered system. Insulation boards are tacked down (though the fasteners are spaced farther apart than in a fully adhered system) and the seams can be heat-welded together. In a mechanically fastened system, the membrane sheets are fastened to

the substrate at certain intervals, depending on specifications.

A *ballasted roofing system* has the simplest installation process. Insulation is loose laid, and gravel is layered on top of the single-ply membrane, holding the system in place. This causes the roof to take on a grayish color (mitigating solar heat gain somewhat when a black membrane is used). In areas where river-washed gravel is readily available, this is the least expensive installation process.

### Costs of single-ply roofing systems<sup>73</sup>

To examine the prices of single-ply roofing systems, we have collected data for several roofing options from one location, Austin, Texas, and compared them to costs for specific projects in three other locations. The data demonstrate that PVC has the highest installed cost of the three major single-ply roofing materials. On a cost per year basis, PVC's disadvantage is likely even greater due to its shorter expected lifetime, as documented above.

Energy Star initiatives have increased the use of white roofing membranes in Texas. Many localities, including Austin, offer rebates for increased insulation or use of white reflective membrane. In these areas, PVC maintains its market share in part because it is slightly easier to heat weld in warm climates. In addition, TPO is relatively new to the roofing membrane industry and thus introduces reliability concerns, making some institutions reluctant to switch to TPO. EPDM is less popular in Austin, despite its low cost, due to the interest in white roofs for energy conservation.

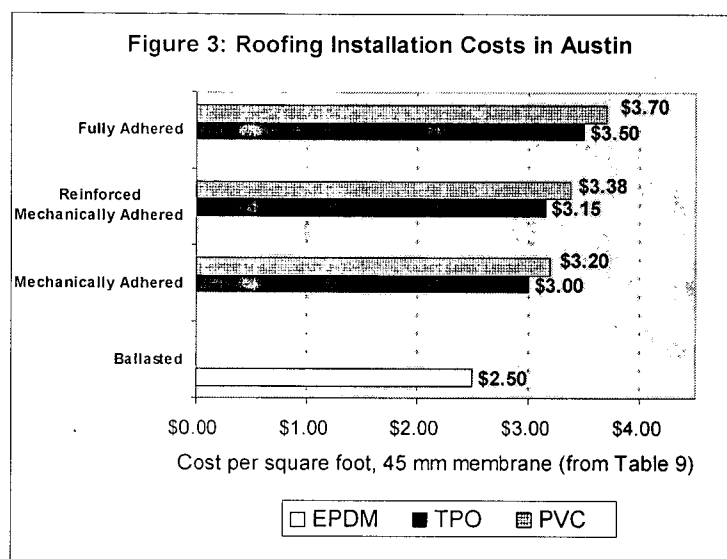
Table 9 compares the costs (including material and installation labor) of EPDM, TPO, and PVC roofing options for commercial roofs in the Austin area. Figure 3 presents the same data graphically for 45 mm roofing membranes. As these figures show, the cheapest roofing option considered here is ballasted EPDM, while fully adhered TPO and PVC have the highest costs.

The range of variation among these costs is not enormous and will not necessarily be decisive in every decision-making process. The highest price shown in the table is less than 150 percent of the lowest price. However, it is clear that TPO is less expensive than PVC in all cases, for all methods of installation and for both membrane thicknesses. Ballasted EPDM roofs, despite their comparative energy inefficiency, have lower installed costs than any of the alternatives.

**Table 9: Installed Costs of Roofing in Austin**  
(costs per square foot for materials and labor)

	Ballasted			Mechanically Adhered		Reinforced Mechanically Adhered		Fully Adhered	
Thickness	EPDM	TPO	PVC	TPO	PVC	TPO	PVC	TPO	PVC
45 mm	\$2.50	\$3.00	\$3.20	\$3.15	\$3.38	\$3.50	\$3.70		
60 mm		\$3.15	\$3.38	\$3.30	\$3.53				

Source: Fifth Wall Roofing (<http://www.fifthwallroofing.com/>)



Similar costs and conclusions can be observed elsewhere. For instance, a recent project in Chicago installed 140,000 square feet of roofing on a commercial building.<sup>74</sup> The total project cost was \$400,000 for materials and labor. Thus, the installed cost was \$2.86 per square foot, similar to costs observed in Austin. The material selected was TPO.

In this case, the choice of TPO was driven primarily by the fact that the TPO installed price was 5 percent lower than that of PVC (which is consistent with the Austin data in Table 9). Labor estimates were equivalent for PVC and TPO; the difference in installed price reflected differences in material costs. Given similar performance characteristics and warranties between PVC and TPO, the contractor

indicated that this was a relatively simple decision in which the deciding factor was materials price.

Somewhat higher costs, but the same general conclusion—PVC is the more expensive choice—can be found in recent experience in western Massachusetts. Two similar school buildings, in the towns of Longmeadow and Chicopee, recently replaced roofs of about 120,000 square feet. The one that specified vinyl paid \$916,000, while the one that did not specify a material paid \$679,000 for a TPO roof.<sup>75</sup> The difference in cost between these two roofs—roughly \$7.60 versus \$5.70 per square foot—reflects not only material prices but also differences in labor costs.

### *Alternatives to PVC, III: Flooring*<sup>76</sup>

Flooring manufacturers sold 7.9 billion square feet of hard floors in 2002, with a wholesale value of \$7.1 billion. Vinyl accounted for 3.6 billion square feet, and \$1.84 billion of these totals—45 percent by area and 26 percent by value. Roughly two-thirds of vinyl flooring is installed in residential buildings and one-third in commercial and institutional buildings.<sup>77</sup>

PVC primarily competes with other resilient flooring materials—a category that includes all major floor surfaces except wood, ceramic tile, and carpet. Resilient flooring options range from natural cork and traditional linoleum through synthetic rubber products and new non-chlorinated polymers. Vinyl flooring is advertised as a uniquely affordable, durable, and easily maintained product. However, while vinyl generally minimizes initial costs of purchase and installation, it is not usually the longest-lasting choice, nor the easiest or cheapest to maintain. Its higher maintenance costs can actually make it one of the most expensive flooring options on a life-cycle basis.

Our analysis starts with a description of the leading options for resilient flooring, then compares the life-cycle costs of these options, and concludes with case studies of decisions between vinyl and linoleum flooring in three cities.

#### **Resilient Flooring Options**

##### *Vinyl*

Vinyl flooring materials contain varying amounts of plasticizers, stabilizers, and fillers. Plasticizers make the naturally rigid PVC pliable. However, the vinyl can become brittle as the plasticizer separates from the polymer over time; stabilizers are used to slow this separation. A filler compound, generally pulverized limestone, is present in vinyl composite tiles (VCT); some VCT products contain as little as 13 percent vinyl by weight.<sup>78</sup>

Health concerns associated with use of vinyl flooring include possible adverse effects on respiratory health during ordinary use as well as toxic emissions in case of fire. For example, a 1999 study in Norway found an association between use of PVC flooring in homes and increased likelihood of bronchial obstruction in young children.<sup>79</sup> In case of fire, vinyl flooring can

give rise to hydrochloric acid fumes, dioxin emissions, and other toxic substances (see earlier discussion of fire risks).

These health concerns, as well as life-cycle cost calculations, have prompted interest in alternatives to vinyl flooring. A number of resilient flooring alternatives are available, with varying characteristics and advantages.

##### *Cork*

Cork is harvested from the cork oak tree (*Quercus suber*), found mainly in Portugal, Spain, and North Africa. The trees live to be 300 to 400 years old; once they are 50 years old, they can be harvested every nine to ten years—a process that involves careful removal of only the outer layer of the bark, allowing the tree to survive. Due to the infrequency of the harvest and its expense, all harvested material, including the cork dust, is used. Some cork tiles also have a recycled rubber backing.

After the manufacturing process, cork tiles are either left unfinished or finished with a wax or polyurethane topcoat. The most durable option, and the one best suited to commercial applications, is the polyurethane topcoat; refinishing with polyurethane is required only every three to four years.

Cork can be extraordinarily long lasting; some cork floors that were installed in the early twentieth century are still in use. Examples include the US Department of Commerce Building in Washington, D.C., and St. Mary's of the Lake Chapel near Chicago.<sup>80</sup>

##### *Linoleum*

A classic of decades past, natural linoleum floor covering is made from renewable materials: linseed oil, pine or other rosin, ground cork dust, wood flour, mineral fillers, and pigments. Linoleum products, available in both sheet and tile, have a natural jute or polyethylene backing depending on the manufacturer. Due to its material composition, linoleum is inherently anti-static and anti-bacterial.

Of the raw materials that compose linoleum, environmental concerns have been raised about volatile organic compound (VOC) emissions associated with linseed oil. However, according to a

test performed by the California Department of Health Services, the average VOC emissions level for linoleum falls toward the low end of the range of emissions by vinyl products and by carpets: 170 micrograms of VOCs per square meter per hour for linoleum, compared to 80 to 600 for various carpets and 120 to 2300 for a range of vinyl products. Stratica (discussed below) had emissions of less than 10, which is below the level the test could detect.<sup>81</sup>

Linoleum was once manufactured widely in the United States; however, as demand began to fall in the 1950s, the industry declined here, with the last US plant closing in 1975. Today, natural linoleum is still produced in Europe; an estimated \$20 to \$25 million worth of linoleum is imported into the United States annually.<sup>82</sup> The product's image has prospered, even if the industry producing it did not: in building supply stores such as Home Depot, "linoleum" now refers to a different product, namely vinyl floor coverings designed to look like traditional linoleum.

#### *Non-vinyl Polymer Flooring: Stratica*<sup>83</sup>

Stratica is a proprietary resilient floor covering material manufactured by Amtico in both European and US plants. Its topcoat, DuPont's Surlyn, was originally developed as an outer surface for golf balls. Surlyn is heat-fused to the Stratica base and is responsible for the floor covering's durability and low maintenance requirements. It is the resilient floor material most similar to vinyl flooring in appearance, with a high-gloss (yet low-maintenance) surface.

Stratica is a low-VOC material that is non-allergenic and mildew and odor resistant. Introduced to the United States market in 1997, Stratica boasts a 100 percent recovery rate for its post-industrial waste. Post-consumer Stratica waste can be recycled into backing for more Stratica flooring; however, facilities do not yet exist for this process in the United States.

#### *Rubber*

Rubber floor covering, available in both tiles and sheets, can be made from natural rubber, from recycled automobile and truck tires, or from synthetic rubber compounds including styrene butadiene rubber (SBR), ethylene propylene diene monomer (EPDM), nitrile, or the proprietary Nora rubber.

Health and environmental concerns vary widely with the composition of the rubber floor material. General concerns have been raised about VOC emissions and the overall impact on indoor air quality, particularly

for products made from recycled tires and/or styrene. Carbon black dust, emitted by some rubber products, also raises concerns about indoor air quality. The manufacturing process for SBR products creates potential worker health hazards.<sup>84</sup>

Rubber is also suitable for use under a wider range of conditions than some alternatives; both cork and linoleum tend to swell when exposed to consistent moisture. Rubber flooring has the advantage of requiring very little maintenance.

#### **Life-Cycle Costs**

Data gathered from floor specialists and distributors in three cities--Austin, Washington, and Chicago--reflect the cost of materials and installation, as well as regular maintenance requirements and estimated costs for common maintenance functions for heavily used commercial and institutional floor space.<sup>85</sup> Costs for leading resilient flooring materials over a 20-year life cycle are shown in Table 10.

Table 10 shows the initial costs, expected life span, annual maintenance costs, and 20-year life-cycle costs of selected brands in five categories of flooring materials: vinyl, cork, linoleum, non-chlorinated polymer (Stratica), and rubber. All costs are presented on a per square foot basis. The table demonstrates the substantial importance of maintenance costs.

Initial material and installation costs are as low as \$2.65 per square foot for vinyl tile and range from \$5.50 to \$11.70 for other materials. Based on initial material and installation costs alone, an institution could spend as little as about \$2,700 to install 1000 square feet of vinyl composite tile (VCT), or two to four times that amount for a higher-end floor. Thousands of dollars of initial savings are apparently available by choosing vinyl tile—the high-end rubber floor shown in this table (Flexco-Radial, last line of Table 10) would cost \$9,000 more than vinyl tile for a 1000 square foot installation.

However, flooring installation represents a very small part of total cost when expressed in terms of cost per year of use. Far more important is the annual maintenance cost; the data in Table 10 show that for heavy-traffic areas maintenance costs account for at least 98 percent of the life-cycle cost for each flooring material.<sup>86</sup> The high-end rubber floor has the lowest maintenance costs per square foot, and therefore the lowest life-cycle costs over all. Over 20 years, it would save more than \$500 per square foot,

compared to the “low cost” vinyl tile. Cork, the second-most expensive product in Table 10 in terms of first cost, is the second cheapest on a life-cycle basis due to its low maintenance costs and long lifetime. Stratica is also a bargain compared to vinyl;

linoleum is cheaper than vinyl on a life-cycle basis, although more expensive than several of the other alternatives. In short, the initial cost savings from vinyl are counterbalanced by high costs over the life cycle of the flooring.

**Table 10: Life-cycle costs of flooring (per square foot)**

Material	Brand - type	Initial cost: material and installation	Expected life span (years)	Initial cost per year of life span	Maintenance cost per year	Total cost over 20 years *
		A	B	C = A / B	D	E = (C + D) * 20
Vinyl	Armstrong - Solid Vinyl	\$9.70	25	\$0.39	\$52.00	\$1,048
	Armstrong - VCT	\$2.65	15	\$0.18	\$52.00	\$1,044
Cork	Dodge - Regupol	\$7.25	40	\$0.18	\$25.70	\$518
	Expanko	\$10.30	30	\$0.34	\$25.70	\$521
Linoleum	Armstrong	\$6.30	25	\$0.25	\$40.00	\$805
	Forbo - Sheet	\$5.50	35	\$0.16	\$33.30	\$669
	Forbo - Tile	\$6.42	25	\$0.26	\$33.30	\$671
Non-chlorinated polymer	Amtico - Stratica	\$6.75	40	\$0.17	\$32.00	\$643
Rubber	Dodge - Regupol-Econights	\$6.50	30	\$0.22	\$40.00	\$804
	Dodge - Regupol-Ecostone	\$7.75	30	\$0.26	\$40.00	\$805
	Expanko - Treadmaster	\$7.50	30	\$0.25	\$32.00	\$645
	Flexco - Radial I, II	\$11.70	35	\$0.33	\$24.00	\$487

Source: Center for Maximum Potential Building Systems (Austin, Texas), based on communications received in September 2003 from Terry Bessire, Intertech Flooring (Austin); Kim Pexton, Jim G. Davis Construction Corporation, and Lesa Green, Turner Construction Company (Washington, D.C.); and Gail Bothwick, Farr Associates (Chicago).

A similar conclusion emerges from a US Navy assessment of decking materials for its ships.<sup>87</sup> In that assessment the Navy tested Stratica in high-traffic areas (such as food service areas) on ten ships, covering a total of 37,800 square feet. Due to the heavy use, the estimates of the lifetimes were shorter, 10 years for Stratica versus 5 for vinyl tile; the Navy also found that Stratica required about one-third as much labor for maintenance. The maintenance costs were by far the dominant factor, as shown by the Navy's analysis of costs over a ten-year span, summarized in Table 11. The Navy estimates that the maintenance costs per square foot per year (one-tenth of the ten-year maintenance and repair figures shown in Table 11) are about \$20 for Stratica and \$59 for vinyl, compared to \$32 for Stratica and \$52 for vinyl reported in Table 10.

The high maintenance costs shown in Tables 10 and 11 may be interpreted as worst-case estimates, appropriate for the heaviest-use areas. For example, the Navy's food service areas on major ships are presumably very high-traffic areas, with hundreds of sailors moving through them several times a day. In

contrast, many offices, stores, and institutions experience much lower traffic and likely have correspondingly lower floor maintenance costs.

**Table 11: Life-cycle costs of Stratica vs. vinyl**

	(\$/sq. ft. over 10 years)	
	Stratica	Vinyl tile
Purchase and installation	\$7.00	\$6.25
Repair	\$4.00	\$6.50
Maintenance labor	\$192.24	\$587.78
Total	\$203.24	\$600.53

Source: "Implementation Assessment for Maintenance Free Decking," memorandum prepared for the Under Secretary of the US Navy by the Commander, Naval Supply Systems Command (January 14, 2000).

However, the key conclusion to be drawn from Tables 10 and 11—vinyl tile is more expensive than other flooring options on a life-cycle basis, due to its

high maintenance costs—would remain true even if maintenance costs were substantially lower. Recalculation of Table 10, assuming 1 percent of the reported maintenance costs for each material, would still find both vinyl tile options to be more expensive over 20 years than any of the alternatives. Even at this reduced level, maintenance costs would still represent more than half of the life-cycle costs for 10 of the 12 options in Table 10. Similarly, recalculation of Table 11 assuming 1 percent of the Navy's repair and maintenance costs would still find Stratica to be cheaper than vinyl over 10 years.

### The Maintenance Costs Puzzle

The conclusion that vinyl flooring has higher life-cycle costs than the alternatives rests on two facts shown in the tables above. First, the lower-cost vinyl option, VCT, has the shortest lifetime of any of the materials shown in Table 10; its installed cost *per year of life span* is actually higher than for some of the alternatives (see column C in Table 10). Second, the maintenance cost per square foot is higher for vinyl than for any of the alternatives.

It may seem surprising that vinyl floors have higher maintenance requirements than the alternatives in commercial and institutional settings. In contrast, sales of vinyl flooring to residential customers rely on the claim that vinyl is the "maintenance free" choice. There are several likely explanations for the differing evaluations of maintenance needs. Virtually any commercial or institutional flooring gets heavier use than most residential floors; for this reason, residential and commercial vinyl flooring are somewhat different in material composition, leading to different maintenance requirements.<sup>88</sup> In addition, there are often higher standards for glossy appearance of floors in nonresidential areas, despite the heavier traffic. (See the Austin case study, below, for more on high-gloss standards.)

Because standard maintenance regimens for vinyl flooring represent significant expenses, some commercial vinyl flooring products are starting to offer lower-maintenance options: for example, urethane wear finishes that reduce the frequency of strip and wax cycles, or new commercial finish products that require only annual application and eliminate the need for stripping. Product developments of this kind could lead to reduced maintenance costs in the future.<sup>89</sup> The data in Table 10 reflect price comparisons as of 2003, based on actual industry data in several regional markets. In addition, changes in the maintenance protocols for other flooring products could affect their

maintenance costs as well. Forbo, a major vendor, promotes dry maintenance of its linoleum flooring; this is a source of significant maintenance-related savings when linoleum is used rather than vinyl. In contrast, Armstrong, another leading vendor, recommends the use of higher-cost polish and wet maintenance methods for linoleum in order to produce a gloss finish similar to that of vinyl. The company contends that this method has performance benefits as well, although Armstrong's warranty is not affected by the cleaning regimen adopted.<sup>90</sup>

### Case Studies: Vinyl versus Linoleum

The choice among rival materials for resilient flooring is debated in countless design projects, involving a mixture of economic, engineering, and environmental considerations. To look more closely at the prospects for alternative materials, we examined specific design decisions in buildings in Austin, Washington, and Chicago—all of which involved the choice between linoleum and vinyl. The results were mixed: some found linoleum to be comparable to vinyl in performance and lower in maintenance costs, as well as preferable on environmental grounds; others faulted the performance of linoleum, or were unable to resist the lower installed cost of vinyl.

#### *Austin, Texas*<sup>91</sup>

The University of Texas at Austin has used a variety of flooring material for student residence halls: linoleum flooring (both sheet and tile), vinyl sheet, and VCT flooring. Three university floor areas in two buildings have used linoleum and vinyl products from the same supplier, Forbo.

One building has a sheet vinyl floor installed in the ground floor lobby, and linoleum tile in the second floor lobby. An older dormitory has linoleum sheet flooring. In the first building, the university is generally satisfied with the linoleum tile, but notes that it does not achieve the sheen of the vinyl product on the first floor. That vinyl floor is the university's favorite in terms of maintenance and appearance.

In the building with the linoleum sheet installation, the lack of sheen is also a concern; there is a sense that the linoleum doesn't respond as well as the sheet vinyl to spray buff maintenance between reapplications of new polish. This older building is subject to periodic water leaks and the linoleum has bubbled as a result of water exposure. The lack of moisture resistance appears to be the linoleum's main

vulnerability. Leaks at building doorways, window leaks, and water fountains have created several urgent repair situations. A similar pattern of problems has not appeared with vinyl products.

Each of the three installations is nine to ten years old. The university's perception is that the vinyl sheet product has been the easiest to maintain, had the least problems, and upheld its appearance the best. Because these facilities are used 24 hours a day, every day, application of new polish only occurs during shut-down periods between semesters. Spray-buffing is relied on for standard, frequent maintenance between reapplications of polish.

In general, people expressed a surprising degree of concern about the lack of a gloss finish on linoleum flooring. An adjustment in expectations might be expected as part of a market transformation process, so that individuals come to understand that a floor does not need to be glossy in order to be clean. Some of the savings available from the use of linoleum disappear if the maintenance protocols required for vinyl are used, unnecessarily, in order to achieve the same level of gloss found with vinyl flooring. It may be important to train maintenance crews in the differences between vinyl and linoleum products. Without such training, in a building where both types of flooring are present, maintenance staff may default to known maintenance procedures, which have been developed for vinyl.

#### *Washington, DC*<sup>92</sup>

We examined two recent projects in Washington. In one federal building, the Government Services Administration (GSA) selected linoleum to cover approximately 3,000 square feet instead of VCT. Installed costs for VCT were estimated at \$1.50 per square foot (even lower than the cost shown in Table 10); thus it was about \$5.00 per square foot cheaper than linoleum. Nonetheless, linoleum was chosen for two reasons: first, a rapidly renewable and environment friendly product would complement the Leadership in Energy and Environmental Design (LEED) program for green building design; second, linoleum was projected to cost less to maintain over the life of the product than VCT. Project managers also took into account the fact that the wear characteristics of linoleum are about the same as VCT.

In another project, a major architectural design firm used linoleum for a 40,000 square foot renovation in its Washington office. The differential in installed cost per square foot was again about \$5.00 per square

foot. The designers were well versed in environmental sustainability issues and felt strongly about using environment friendly surfaces in the space. They typically recommend linoleum in lieu of VCT in all of their projects.

#### *Chicago, Illinois*<sup>93</sup>

The Interfaith Single Room Occupancy (SRO) project, under construction in Chicago in 2003, aims to provide permanent housing for 63 single, homeless women and six families. One environmental goal of the building design was to choose materials with low VOC emissions. At the same time, the project had a tight budget. Both of these factors influenced flooring choices.

As a nonprofit enterprise constructing a residential building, the Interfaith SRO project faced different, and lower, costs than commercial buildings; maintenance requirements, in particular, are lower, since many parts of the building will experience much less traffic than an office or other business establishment. However, the general pattern was the same: vinyl flooring had a lower first cost, while linoleum had lower maintenance costs and a lower overall life-cycle cost.

Project managers originally intended to use linoleum because of its ease of maintenance as well as its low VOC emissions. Vinyl, with its more complex maintenance requirements and potential to aggravate respiratory problems, was not their preferred option. However, the higher first cost of linoleum installation was a burden for the project's limited finances. In the course of research for this project, a supply of unused vinyl flooring was found in a closed factory. As the flooring was headed to the landfill, using the material was thought to be a more environmentally sustainable option; and the installed price of the product was unusually low given the circumstances—less than half the price of ordinary VCT.

Ultimately, project managers settled on a compromise in which the resident's apartments and townhouses, accounting for half the floor space in the project, would have the bargain-priced vinyl flooring and all public spaces would have linoleum. The vinyl product that was available would not have been suitable for high traffic areas, such as hallways and recreation areas, where the linoleum was placed.

#### *Lessons from Case Studies*

Our case studies, selected from recent experience with environmentally conscious ("green building")

initiatives, show that the case for alternatives to vinyl is not yet as widely accepted in flooring as, for instance, in roofing. Characteristics favoring vinyl flooring include the ease of maintaining a traditional high-gloss appearance and the appeal of low installed costs for severely budget-constrained buyers.

However, our analysis suggests a number of additional considerations that could tip the balance toward the alternatives. The low installed cost of vinyl is often misleading; on a life-cycle cost basis, other products are often cheaper. There is a wide range of alternative materials, no one of which is right for every application; one possible inference from the case studies is that some green building efforts may have overemphasized linoleum at the expense of other alternatives. Cork provides an equally natural, renewable flooring with a very long lifetime and low maintenance costs; rubber offers water resistance and the lowest life-cycle costs in some circumstances; and Stratica combines a vinyl-like, high-gloss appearance with minimal maintenance and lower life-cycle costs than vinyl. Despite some environmental concerns of their own, each of these materials offers a potentially promising alternative to PVC.



### *Alternatives to PVC, IV: Medical Supplies and Gloves*

Medical supplies account for less than 3 percent of total PVC use.<sup>94</sup> Nonetheless, PVC medical products have significant and troubling implications from a public health perspective, due to leaching of plasticizers from medical equipment as well as the hazard of dioxin formation when medical waste is incinerated.<sup>95</sup>

The bulk of PVC use in disposable medical devices occurs in three types of products: gloves, bags, and tubing. Each of these categories has multiple sub-categories with distinct requirements. For example, the broad category of bags includes IV bags, which may hold medications, nutritional fluids, or saline solutions; total parenteral nutrition bags, which are used to feed patients intravenously when they cannot eat; and a variety of bags used to store blood, including bags for whole blood and bags for individual blood components such as red blood cells or platelets. Multiple alternatives to PVC exist in each area; bags can be made from materials including nylon, ethylene vinyl acetate (EVA), polyethylene (PE), polypropylene (PP), and polyolefins. Tubes can be made from materials including silicone, polyurethane, and rubber.<sup>96</sup>

For the most part, the raw materials available for manufacture of PVC-free bags and tubes are somewhat more expensive than PVC on a per pound basis. Partially counterbalancing this greater materials cost, some alternatives are inherently stronger than PVC, requiring less raw material for a similar product or providing greater durability. In manufacturing PVC-free bags, for example, manufacturers can partially offset the higher materials cost through downgauging (using a thinner sheet of the alternative product) and eliminating extra materials (PVC bags must be wrapped in an extra bag to prevent volatilization of plasticizers and resulting loss of flexibility before use; non-PVC bags do not require this overwrap).

For example, leaching problems arise with some types of tubing. Like other pliable PVC products, PVC medical tubing—which includes products ranging from IV tubes to parenteral nutrition systems to enteral feeding tubes—derives its flexibility from the addition of plasticizers. These plasticizers leach out of the PVC tubing to varying extents, depending on how they are being used. One recent study found that after 24 hours inside an infant's stomach, PVC feeding tubes had lost half their plasticizer content.<sup>97</sup>

In cases where the tubing is inside the patient's body, the leaching of plasticizers not only introduces a toxic substance directly into the patient's body, it also decreases the flexibility of the tubing over time. The health effects of plasticizers in children's bodies may be subtle or delayed, making them difficult to track, but if a feeding tube becomes brittle and unusable, this effect is readily observed. Alternatives such as silicon are substituted for PVC for longer term uses.

### **Costs, Institutions, and Medical Purchasing**

There is wide variation from one product category to the next in the availability and prices of non-PVC gloves, bags, and tubing. In some cases, non-PVC alternatives are currently available on the market at competitive prices. For example, cost-competitive alternatives are available for IV bags, platelet and fresh frozen plasma bags, and oxygen masks.<sup>98</sup> In other cases, non-PVC alternatives cost more than PVC devices but also present clear performance advantages, such as greater durability.

The full cost implications of choosing a given material involve a range of factors, including performance and durability of the product. In addition, supply and demand interactions affect costs over time. Demand for products made from safer materials can provide the impetus for manufacturers to invest in new equipment to launch production.

The evolving institutional structure of American medicine makes it difficult to analyze the markets for individual medical supplies. Health care institutions increasingly purchase medical devices via group purchasing organizations (GPOs). Through GPOs, health care institutions are often able to place large orders and receive substantial discounts through bundling of purchases. A vendor may supply many products, for use at many locations, under a single agreement with a GPO.

Due to the size and market power of the institutions involved, the prices actually paid for medical devices are affected by the volume in which they are purchased. The price of an order of surgical gloves or IV bags, for example, is often negotiated as part of a larger package that includes many other medical supplies. The negotiated price may depend on the total volume of the supplies of all types bought by the GPO. Therefore, prices for the same good offered by

different vendors, or paid by different purchasers, may not be strictly comparable to each other.

Still, it is possible to make some broad comparisons on the basis of advertised prices. In the remainder of this section, we focus on the factors that influence choice of materials for medical gloves in particular. We look at variations in prices of gloves intended for use in medical settings, using the prices quoted to us by a vendor—which may be higher than the price that would be negotiated by a major GPO.

### Gloves in Medical Settings

Disposable gloves are used in medical settings to prevent disease transmission and as a barrier to chemicals and chemotherapy drugs. Materials used in high volume for examination gloves, which are the focus of our discussion here, include latex, PVC, and acrylonitrile (also known as nitrile). Other glove materials include neoprene, another chlorinated plastic; Elastrin, a proprietary elastomer; and polyurethane. Surgical gloves may be made from materials including latex or nitrile; PVC is not approved by the FDA for use in surgical gloves because it is not considered strong enough for the conditions of surgery.

In many hospitals, gloves are also used by food service workers to prevent direct contact between their hands and the food they prepare. For food service settings, polyethylene gloves offer a low-cost, effective option. These gloves do not need to be of medical quality since they are not acting as protection against bloodborne pathogens.

#### *Latex allergies and the need for alternatives*

Latex, made from natural rubber, was the material of choice in medical settings for many years. However, with rising frequency of glove use in health care in the late 1980s and 1990s, large numbers of health care workers and others developed allergies to latex.<sup>99</sup> The mildest symptoms of latex allergy can be similar to hay fever; more severe reactions include hives, asthma, and dangerous swelling of the face, mouth, and airway. At its most severe, latex allergies can produce anaphylactic shock, a severe and frequently fatal reaction that can involve swelling of the throat and a sudden decline in blood pressure. Thus, it has become imperative that health care institutions identify alternatives to latex gloves in order to protect their workers, patients, and visitors.<sup>100</sup>

In the context of increasing problems with latex allergies, many health care institutions are now looking at the relative merits of vinyl and nitrile gloves. While these alternatives are less acutely toxic than latex to health care providers and patients, there is no entirely non-toxic glove material on the market. As we have seen, the manufacture and disposal of PVC products is associated with the production and release of toxic and persistent chemicals. Acrylonitrile can also pose health hazards as a pollutant at hazardous waste sites where it has been discarded and in air, soil, and water near industrial facilities where it is produced, although acrylonitrile breaks down relatively rapidly and does not bioaccumulate.<sup>101</sup>

Most latex and many nitrile gloves contain accelerators—chemicals added to facilitate the manufacturing process and ensure that gloves are strong and resilient. Some health care workers exposed to accelerators in gloves can develop allergic contact dermatitis, a form of skin irritation producing itching and blistering lesions similar to those associated with a poison ivy reaction.<sup>102</sup> Some companies now provide accelerator-free nitrile gloves. While accelerator allergies can be a serious problem, they are not on the order of latex allergies, because they do not produce a systemic reaction and are not as widespread.

#### *Performance evaluation*

Glove performance can be judged in terms of multiple characteristics, including durability, barrier quality, and tactile properties. Barrier quality is the ability of a glove to prevent transmission of pathogens carried in blood or other fluids and is linked to over-all durability. Tactile properties refer to the extent to which the glove allows normal sensation in the hand.

Gloves can be subjected to a variety of tests to gauge their reliability as a barrier to disease transmission. Some of these tests are required by the US Food and Drug Administration (FDA); others are voluntary. Testing requirements depend on the intended use of the product; for example, gloves for use with chemotherapeutic agents are in the highest class and require more rigorous testing than examination or surgical gloves.<sup>103</sup>

Most tests that assess the durability and barrier quality of medical exam gloves are best suited to detecting gross manufacturing problems. Often, the gloves are simply filled with water and tested for leaks. More sensitive tests have also been developed

in which the glove material is placed in contact with a fluid containing a virus, and the material is tested for permeability to the virus. For example, the ASTM F 1671 test looks at the ability of the glove material to protect against blood-borne pathogens, such as viruses.<sup>104</sup> FDA does not require manufacturers to test glove effectiveness in preventing movement of viruses across the glove material, but some manufacturers carry out this test voluntarily. Other tests are available to measure the ability of gloves to protect against chemicals used in medicine, such as chemotherapy drugs.

A recent study compared barrier integrity of latex, nitrile, and PVC gloves.<sup>105</sup> The study looked at barrier integrity of each glove type both in "static" conditions, in which the glove was simply removed from the box and tested, and in conditions of activity, in which the glove was manipulated to simulate actual use in health care. The gloves were subjected only to the test for water leaking; more sensitive tests were not attempted.

The researchers found dramatic differences in the gloves' barrier integrity after manipulations simulating the kinds of activity for which gloves are commonly used, such as connecting and disconnecting a syringe or wrapping, taping, and unwrapping a blunt object.

The researchers tested four brands each of vinyl and latex gloves, and two brands of nitrile gloves. They found that for all nitrile and latex gloves tested, the failure rate ranged from 0 to 5 percent. For vinyl gloves, there was greater variation among brands; three brands had failure rates from 1 percent to 3 percent when used directly out of the box, while the fourth had a 12 percent out-of-box failure rate. The highest failure rates appeared in vinyl gloves tested after simulated use; these had failure rates ranging from 12 percent to 61 percent.<sup>106</sup> Table 12 shows the average failure rates observed by the researchers for each material, both for gloves tested directly out of the box without manipulation and for gloves tested after manipulations simulating normal use.

The study notes that PVC has relatively poor barrier qualities due to its molecular structure; even when plasticizers are added, "vinyl still lacks the ability to stretch when stressed or snagged, and readily fractures, tears, or separates at the molecular level resulting in barrier loss."<sup>107</sup> The authors conclude that nitrile and latex gloves are significantly more resistant than vinyl to breaking down or leaking during use.

**Table 12: Average failure rates of vinyl, nitrile, and latex gloves**

	Out of box	Simulated use
<b>Vinyl</b>	4.8%	29.8%
<b>Nitrile</b>	3.0%	2.0%
<b>Latex</b>	2.0%	1.8%

Source: Rego and Roley 1999

Vinyl glove examples include both standard vinyl and "stretch" vinyl.

In the case of latex, pores in the material sometimes allow visible leakage; medical staff may find patients' blood on their hands after wearing apparently intact gloves. The Sustainable Hospitals Project at University of Massachusetts-Lowell has even received anecdotal reports of hospital practitioners in an emergency department who routinely put on a double layer of latex gloves to avoid this problem.<sup>108</sup>

#### *Durability and total utilization cost*

The superior barrier qualities and durability of nitrile mean that the difference in cost, relative to performance, is not as great as it appears from the unit prices listed here. A 1999 analysis by Kaiser Permanente, the nation's largest not-for-profit health care organization, found that on a total utilization cost basis, nitrile gloves were cost competitive with the alternatives, due to their greater durability.<sup>109</sup> On the basis of this analysis, Kaiser Permanente decided to switch to nitrile, purchasing 43 million nitrile gloves.<sup>110</sup>

The data used in Kaiser Permanente's cost analysis are not available. As noted above, health care institutions generally purchase medical supplies, including gloves, through large contracts that include multiple types of equipment and supplies. Negotiated prices for these contracts may depend on an institution's total volume of purchases and are generally lower than publicly available "list prices." (In general, anyone purchasing 43 million items might expect to get the lowest possible price per item; other medical institutions are likely to make smaller, but still substantial, glove purchases.) Nonetheless, it is possible to gain some insight into price differences by comparing publicly available list prices. Actual prices paid by health care institutions are likely to be lower than these list prices.

Medical gloves come in a wide variety of sizes and specifications. Glove characteristics that may vary from one product to another include glove length, the diameter of the wrist opening, the thickness of the material, hand orientation (right and left hand gloves produced separately, or ambidextrous gloves), durability, and the level of quality testing that has been applied to the product.

Table 13 shows the prices of vinyl, latex, and nitrile medical exam gloves available through the distributor Fisher Scientific. The gloves used for this example are sold under the distributor's name, as a Fisher brand product, and are among the distributor's most commonly sold varieties. (They are, however, manufactured by three different companies.) The three examples examined here were identified by Fisher Scientific sales staff as being broadly comparable to one another. All are size large, powder free, medical exam grade gloves. According to the sales staff, powdered gloves would cost less for each material, but the ratio among the prices would be approximately the same.<sup>111</sup>

The quality standards that the gloves meet are not identical; in several respects, the standards are lower for vinyl. For example, the percentage of leaks allowed is higher for the vinyl gloves than for the latex or nitrile gloves.<sup>112</sup> The minimum standards for strength and elongation of examination gloves are also lower for vinyl gloves than for latex and nitrile gloves.<sup>113</sup>

Based on the prices available directly from Fisher Scientific, when gloves are purchased in cases of 10 boxes (1000 gloves) each, nitrile gloves cost twice as much as vinyl gloves.<sup>114</sup> The bulk discount available

for cases of 1000 gloves is the maximum bulk discount offered to us by Fisher, so these prices per glove would apply for larger orders as well.

If gloves never failed (or all types failed at the same rate), and equal numbers were used for a task regardless of the choice of material, then the prices in column B would describe the relative costs of different gloves. In particular, using nitrile gloves would cost twice as much as using PVC gloves.

However, because of durability differences among glove materials, it makes more sense to consider the average cost per *glove use*. Thus we build in a "durability factor" to reflect the average measured failure rate for each glove type, using the "simulated use" failure rates from Table 12. With this approach, we make the assumption that in every instance in which a glove fails the user discards it and puts on a new glove. In other words, we assume that vinyl gloves will be discarded and replaced due to failure in 30 percent of all uses, while nitrile and latex will be discarded and replaced due to failure only 2 percent of the time. This assumption is an approximation for the more complicated reality, in which some glove failures go undetected while in other cases, health care professionals may wear a double layer of gloves due to concerns about the gloves leaking or breaking.

As Table 13 shows, building in this durability factor decreases the cost difference between vinyl and nitrile from about seven cents per glove to less than five cents per glove use. Thus, the differential is reduced by about a third through the incorporation of the durability factor.

**Table 13: Durability and Glove Prices**

Material	Price per case of 1000	Price per glove	Average failure rate	Durability factor	Price per glove use
	A	B = A/1000	C	D = 1/(1-C)	E = B*D
Vinyl	\$66.96	\$0.067	29.8%	1.42	\$0.095
Nitrile	\$140.47	\$0.140	2.0%	1.02	\$0.143
Latex	\$154.71	\$0.155	1.8%	1.02	\$0.157

Prices from Fischer Scientific sales staff.  
Average failure rate is for simulated use conditions, from Table 12.

Anecdotally, there are other advantages to switching to nitrile as well. For example, the Sustainable Hospitals Project has been in contact with hospitals that found certain important, though nonquantified, practical benefits associated with switching to nitrile across the board and eliminating all other glove materials. One hospital that previously stocked over 80 different glove types and brands was able to switch to fewer than ten when the hospital began purchasing only nitrile gloves; in addition, the hospital no longer had to make special arrangements for susceptible staff to avoid latex.<sup>115</sup>

#### *Glove costs in context*

How much of a difference glove prices make to a health care institution's overall budget depends on how many gloves are consumed per patient and how much the institution spends per patient as a whole. The federal *National Hospital Indicators Survey* provides overview statistics on expenditures and revenues at community (non-teaching) hospitals in

the US. These hospitals were estimated to spend \$1,318 per patient day for inpatient care, and \$265 per outpatient visit.<sup>116</sup>

These total cost figures can be used to put glove costs in context. For example, if five pairs of gloves (ten individual gloves) are used per patient-day, switching from PVC to nitrile gloves would increase glove costs per patient-day from slightly under a dollar a day to slightly under \$1.50 a day, a difference of about 48 cents in total expenditures per patient-day, or an increase of less than 0.04 percent of total expenditures per inpatient patient-day. If ten pairs of gloves (twenty individual gloves) are required per patient-day, the switch would increase costs by about one dollar, or less than one-twelfth of a percent (less than 0.08 percent) of expenditures per patient-day. The costs discussed here, of course, do not include any calculation of the costs of illnesses that could be transmitted due to glove failures.

### *Alternatives to PVC, V: Siding and Windows*

The fastest-growing uses of PVC, and the largest after pipes, are vinyl siding and windows. As seen in Table 1, early in this report, siding and windows experienced double-digit annual growth rates throughout the 1990s and now represent about 20 percent of all PVC use in the US and Canada. Here we examine these areas briefly; our discussion of siding relies heavily on the August 2003 *Consumer Reports* survey, which offered a comprehensive review of the available alternatives. Our discussion of windows draws on a number of construction industry sources.

#### **Siding**<sup>117</sup>

Vinyl is now the most common siding material for low- and moderate-priced housing, but it is not the only product on the market. Wood shingles or clapboard also offer viable siding alternatives, as do fiber cement and simulated stucco. Aluminum, an important alternative in the past, has all but vanished from the market and is not discussed here.

#### *Vinyl*

Vinyl siding is available in a variety of colors, thicknesses, and qualities. Installation is easy, and vendors tout vinyl as "maintenance free." Vinyl is known for its ability to mimic other looks such as wood. It is often said to be resistant to water damage; it is also impervious to insects.

Unfortunately, vinyl siding can warp if it gets too hot. It is also sensitive to cold temperatures, which can cause it to chip or crack and become brittle, and it expands and contracts with temperature changes. Many home improvement sources contest the common claim that vinyl is not damaged by water; it is often acknowledged that when cleaning or painting vinyl, a homeowner must, much as with wood siding, be careful to remove all mildew prior to adding a coat of paint. Vinyl presents the additional problem that it can burn or smolder, threatening the health and safety of people in or near a burning house, as well as the health and safety of firefighters.

Vinyl generally fades with time, although some higher end sidings now include UV protection to limit the amount of fading that can occur. Once the color has faded, it may need to be painted, requiring specific paints and processes to ensure the desired

look. After the vinyl has been painted, it will need to be repainted in time, although the frequency depends on the quality of paint used—high-quality paint can last up to ten years, whereas lower-quality paint may last only four years. According to Electrospec Home Inspection Services notes, because of the heat absorption of vinyl, a homeowner needs to be careful not to paint the vinyl a color any darker than the original color.<sup>118</sup>

#### *Wood*

Wood siding is also easy to install, although not as easy as vinyl. It has the added value of being the preferred look for housing: vinyl and fiber cement siding both seek to emulate the appearance of wood siding. Wood can be purchased finished or left natural, and it is impact resistant, even in cold temperatures.

Wood siding, though, can warp, twist, or be damaged by water if not properly maintained. It is also vulnerable to insect damage and burns readily. In order to maintain wood siding properly it does need to be painted or stained repeatedly, although how frequently this is required depends on the quality of the paint used and on the climate.

#### *Fiber cement*

Fiber cement is a newer alternative to wood and vinyl siding and is made primarily from a combination of cement, sand, and cellulose fibers. According to Georgia-Pacific, it is installed much like wood, although carbide or diamond head blades or shears, which are stronger than ordinary sawblades, are suggested in order to preserve the blades. (According to architect Bruce Hampton, some contractors "carry the cost of a saw with each new job" for large scale projects, because the dust damages the saw over time.)

The look created by fiber cement can vary from rough sawn cedar to stucco, depending on its embossing. Fiber cement is available in a number of forms, such as planks or octagon shaped shingles, and can be purchased already primed and painted. It does not warp or twist, is impact resistant, and is impervious to insects. Unlike vinyl siding, it does not expand and contract, nor does it burn or smolder in a fire.

Fiber cement does need to be painted, but it requires painting less frequently than wood siding: Georgia-Pacific notes that some third parties guarantee their coatings for twenty years. However, although fiber cement itself does not burn, products applied to it may. It may also be damaged by water freezing and thawing. The material data sheet for Hardiplank, a brand of fiber cement, warns that the product contains silica. Inhaling silica dust during manufacturing or construction work can cause silicosis, a devastating lung disease. This is a potentially controllable problem; but unless the silica dust is controlled, fiber cement production and installation present health hazards to the workers who make and install it.

#### *Simulated stucco*

Simulated stucco is a relatively new product on the market, offering a very distinct appearance. Sometimes called Exterior Insulation Finish Systems (EIFS), it uses a polymer-based outer coating that contains plastic resin, which makes it softer and more flexible than cement-based stucco, over a cement board sheathing.<sup>119</sup> If it is not applied properly, the material may trap moisture and allow the growth of mold, problems which have sparked a number of lawsuits. If improperly applied, simulated stucco cannot be fixed; it must instead be replaced, possibly along with the wood structural components behind the EIFS barrier.<sup>120</sup> Although it is impervious to insects, it can crack, requiring it to be refinished, and it can burn.

#### *Costs*

The cost of each of these products varies, depending on the quality of the siding. *Consumer Reports* compared the material costs and estimated lifetimes of high- and low-quality siding of each of the alternatives, as shown in Table 14. Some anecdotal reports suggest a shorter life span for vinyl,<sup>121</sup> but we use the *Consumer Reports* estimates for all materials

for the sake of consistency. A simple additional calculation, shown in the last two columns of Table 14, demonstrates that the material cost per year is lowest for fiber cement among lower-quality siding options, and for wood among the higher-quality options. (This is not a complete life-cycle cost calculation, since it does not include installation and maintenance costs.)

#### **Windows**

As in the case of siding, vinyl has become widely used for windows in low- and moderate-priced construction, but it is not the only option on the market. Alternatives to vinyl windows include wood, fiberglass, and aluminum windows. There are also options for repairing old wood windows to improve their energy efficiency. Energy efficiency is a major concern influencing the choice of new or replacement windows.

#### *Vinyl*

The benefits and drawbacks of vinyl windows are similar to those of vinyl siding. Vinyl windows do not rot, but they are sensitive to both hot and cold temperatures, can become brittle, and can incur dents. Often sold as "maintenance free," vinyl windows raise some of the same issues discussed in connection with maintenance of vinyl siding. In addition, the fiberglass industry (i.e., the supplier of a competing product) notes that of all window materials, vinyl has the greatest rate of thermal expansion, which can cause the seal of the window to break early. If this does occur, vinyl windows cannot be fixed and must instead be replaced.<sup>122</sup>

#### *Fiberglass*

Fiberglass is a newer product in windows, and many contractors and suppliers have little experience with it. According to the fiberglass industry, fiberglass is an extremely strong material: three times stronger than wood or wood composite and eight times

**Table 14: Siding Material Costs and Lifetimes**

	Cost per square foot		Estimated lifetime (years)		Cost per 100 sq ft per year	
	Low	High	Low	High	Low	High
Vinyl	\$0.45	\$1.95	25	50	\$1.80	\$3.90
Wood	\$0.67	\$3.46	10	100	\$6.70	<b>\$3.46</b>
Fiber cement	\$0.84	\$2.55	50	50	<b>\$1.68</b>	\$5.10
Simulated stucco	\$1.77	\$2.39	20	30	\$8.85	\$7.97

Source: Cost per square foot and estimated lifetime from "Vinyl Siding: More Uniform Plastic," *Consumer Reports* (August, 2003), pp. 23-25. High-quality vinyl and fiber cement lifetimes were reported as "50+" years. Cost per 100 square feet per year is our calculation from *Consumer Reports* data. Boldface indicates lowest cost in each column.

stronger than vinyl. It does not rust, rot, warp, corrode, crack, or dent. It has the lowest thermal expansion rate of all of the window types, guaranteeing a tight seal. Fiberglass windows are often Energy Star products. They come in standard colors, can have a wood veneer, can be painted to match any color scheme, and can be repainted.<sup>123</sup> Both fiberglass and chemicals often used with fiberglass also pose hazards to human health.<sup>124</sup>

#### *Wood*

Wood windows are traditional, and, as with siding, wood creates the look that alternatives imitate. Wood windows can be repaired and maintained so that they are as energy efficient as vinyl windows.<sup>125</sup> Wood is also an easier material to work with for custom window fits. The drawbacks of wood windows are identical to wood siding: they require painting, may rot, warp, become insect infested, condense, or be damaged by moisture.<sup>126</sup> They can also burn. Although wood windows do not expand at the rate that vinyl does, they do expand quite a bit more than fiberglass or even aluminum.<sup>127</sup>

Many wood frames that are replaced by vinyl could have easily been repaired and, with weather stripping, can become as energy efficient as vinyl windows. Repairing wood windows may be a better alternative to retain the historical character of a building and to cut down on waste.<sup>128</sup> For historic renovation,

repairing wood windows or replacing them with new wood windows is often the only option.

#### *Aluminum*

Aluminum windows are often used to comply with building codes for three-story and higher residential and commercial buildings.<sup>129</sup> Aluminum is a strong, durable material that does not rust and does not normally require paint, although there are some reports that the factory finish may wear off after about 20 years, making painting necessary at that point. Although aluminum has slightly higher thermal expansion than fiberglass, it has less than the other window products, ensuring a stronger and longer-lasting seal.<sup>130</sup> However, thermal breaks must be added to aluminum windows to make them energy efficient.

#### *Costs*

Window costs vary widely based on size, style, and quality; few vendors offer precisely comparable windows made of the full range of materials. One California vendor quoted prices, as of late 2003, for a 6x4 foot window, of \$190 in aluminum, \$225 in vinyl, \$250 in fiberglass, and \$300 in wood.<sup>131</sup> As with siding or other products, differences in installation cost, maintenance and repair cost, and lifetime could be more important than these differences in purchase price.



## Employment Impacts of a PVC Phaseout

Replacing PVC with safer alternatives will change some jobs: from fabricating PVC products to fabricating the same products from other materials, often other plastics; or from making vinyl chloride monomer and PVC resin to making safer substitutes (again, often other plastics). In many cases, the same workers who currently make PVC products are likely to be employed making similar products from PVC alternatives.

More generally, the money that is now spent on PVC products, the uses of those products, and the jobs created by production and use of PVC will not disappear from the economy in the transition to alternative materials. The skills that are needed to make many products out of PVC will still be needed to make the same products out of something else; there is no evidence that the substitutes would require less labor or that resources spent on clean alternatives create fewer jobs than resources spent on PVC.

### *Size of the Industry*

It is surprisingly difficult to determine the total number of workers who are employed in making PVC and PVC products. Industry sources report that there are 126,000 workers in PVC fabrication plants; in addition, as explained below, we estimate from the limited available data that there are 9,000 or fewer workers making vinyl chloride monomer (VCM) and PVC resin.

The 1997 Economic Census, the source of the latest available detailed government data on employment by industry, reports that some 826,000 workers were employed in plastic product manufacturing of all types. However, most of that total is not broken down by type of plastic or product.<sup>132</sup> Industry sources report even larger totals: according to the Society for the Plastics Industry, there were 1.5 million workers in the plastics industry and another 850,000 employed in upstream industries that supplied the plastics industry in 2001.<sup>133</sup> These figures refer to the plastics industry as a whole; most plastics industry workers are not involved with PVC.

Turning specifically to PVC and related activities, another industry group, the Alliance for Responsible Use of Chlorine Chemistry (ARCC), claims that there are 482,000 workers in chlorine-related jobs. This total includes 180,000 employees of dry cleaning

establishments, most of whom use perchloroethylene, a chlorinated dry cleaning fluid.<sup>134</sup> Aside from dry cleaning, the core of the ARCC employment data consists of two categories: 126,000 workers at PVC fabricating plants, and 170,000 workers at chlorine-producing and chlorine-using chemical plants.

Note that the chlorine-producing and chlorine-using plants (which are combined in the ARCC employment figures) are not all involved in the PVC life cycle. Some of the plants are large, multi-product chemical industry facilities with significant numbers of workers making products unrelated to PVC or chlorine. Among the chlorine-using plants, there are enterprises making other products such as pesticides, paper mill chemicals, solvents and dry cleaning fluid. Plants involved in the PVC life cycle are a small fraction of the chlorine-producing and chlorine-using category recorded by ARCC. Our best guess, explained below, is that no more than about 9,000 workers, and possibly fewer, are employed in production of vinyl chloride monomer (VCM) and PVC resin.

The data for the US as a whole and for the eleven states identified by ARCC as the industry leaders are shown in Table 15. The PVC fabricating plants are smaller and pay less, with a national average of 54 workers per plant and payroll of \$27,000 per worker. The chlorine-producing and chlorine-using plants are larger and pay more, averaging 376 workers per plant with a payroll of more than \$45,000 per worker.

Yet another industry source, the *Chemical Economics Handbook*, periodically publishes in-depth reports on vinyl chloride monomer (VCM) and PVC resin production. The latest available reports appeared in December 2000 for VCM, and September 2003 for PVC.<sup>135</sup> In 2000 there were 12 VCM plants in the US, with the capacity to produce 17.4 billion pounds of VCM, as shown in Table 16. Seven of the facilities, accounting for more than half the capacity, were located jointly with PVC plants owned by the same company.

As of mid-2003, ten companies produced PVC resin in the US at twenty locations, as shown in Table 17, for a total capacity of 15.8 billion pounds. Three other plants were idled by the recession, with an additional capacity of 1.2 billion pounds.

**Table 15: Industry Estimates of Chlorine-Related and PVC Fabricator Employment**

	PVC Fabricators			Chlorine-Producing and Using Plants (not all PVC-related)			
	Number of Facilities	Employment	Payroll (millions of dollars)	Chlorine- Producing Plants	Chlorine- Using Plants	Employment	Payroll (millions of dollars)
California	238	12,679	\$342	0	26	6,024	\$266
Florida	91	5,599	\$151	0	3	212	\$10
Illinois	123	4,251	\$115	0	22	7,495	\$334
Louisiana	6	575	\$16	9	22	11,650	\$538
Michigan	123	3,751	\$101	0	16	17,632	\$798
New Jersey	120	7,127	\$192	0	47	17,387	\$771
New York	119	4,723	\$128	3	20	7,154	\$325
Ohio	210	12,138	\$328	2	18	3,877	\$175
Pennsylvania	127	6,864	\$185	0	16	3,552	\$156
Tennessee	54	3,503	\$95	1	12	15,038	\$703
Texas	112	9,048	\$244	6	42	27,268	\$1,262
All other states	1,009	55,457	\$1,497	27	160	52,605	\$2,374
<b>US Total</b>	<b>2,332</b>	<b>125,715</b>	<b>\$3,394</b>	<b>48</b>	<b>404</b>	<b>169,894</b>	<b>\$7,712</b>

Data refer to an unspecified recent (current) year.

Source: Alliance for the Responsible Use of Chlorine Chemistry (ARCC), <http://www.chlorallies.org/employ.html> (viewed October, 2003).

Employment at these plants is not consistently reported in any published source. Through website searches and telephone inquiries we were able to obtain employment data for 14 of the 20 facilities, as shown in Table 17. These data vary in definition from one plant to another. In at least one case, an important category of contractor employees was not included. In some other cases, including the two largest employment entries in Table 17 (the workers at the Formosa and OxyVinyls Texas facilities), the data include other workers as well as those making PVC resin.

Since many facilities produce more than one product, it is hard to avoid uncertainties in the delineation of PVC employment. Nonetheless, using the figures in Table 17 in the absence of better data, the plants where we have employment data average 2.82 million pounds of PVC capacity per worker. If this ratio applied to the other plants as well, total employment in the plants that make PVC resin would be about 5,600. Our guess is that this is, if anything, a high estimate, although we are unable to produce a better figure.<sup>136</sup>

**Table 16: VCM Production Facilities, 2000**

Company	Plant location	Capacity (million lbs)	PVC at same location?
Borden	Geismar, LA	1,000	Yes
Dow	Oyster Creek, TX	2,030	
Dow	Plaquemine, LA	1,500	
Formosa	Baton Rouge, LA	1,475	Yes
Formosa	Point Comfort, TX	880	Yes
Georgia Gulf	Lake Charles, LA	1,000	
Georgia Gulf	Plaquemine, LA	1,600	Yes
Oxymar	Ingleside, TX	2,100	
OxyVinyls LP	Deer Park, TX	1,200	Yes
OxyVinyls LP	La Porte, TX	2,450	Yes
PHH Monomers	Lake Charles, LA	1,150	
Westlake Monomers	Calvert City, KY	1,050	Yes
<b>Total capacity</b>		<b>17,435</b>	

Source: SRI Consulting (Menlo Park, CA), *Chemical Economics Handbook: Vinyl Chloride Monomer* (December, 2000)

**Table 17: PVC Production Facilities, 2003**

<i>Company</i>	<i>Plant location</i>	<i>Capacity (million lbs)</i>	<i>Employment (if available)</i>
CertainTeed	Lake Charles, LA	475	80
Colorite	Burlington, NJ	120	145
Dow Chemical	Texas City, TX	140	
Formosa	Baton Rouge, LA	990	505
Formosa	Delaware City, DE	144	115
Formosa	Illiopolis, IL	320	
Formosa	Point Comfort, TX	1,365	2000
Georgia Gulf	Aberdeen, MS	1,050	174
Georgia Gulf	Oklahoma City, OK	500	50
Georgia Gulf	Plaquemine, LA	1,250	
Occidental	Pottstown, PA	220	310
OxyVinyls LP	Deer Park, TX	555	} 656 *
OxyVinyls LP	Pasadena, TX	2,050	
OxyVinyls LP	Louisville, KY	585	
OxyVinyls LP	Pedricktown, NJ	360	
PolyOne	Henry, IL	125	
PolyOne	Pedricktown, NJ	130	
Shintech	Freeport, TX	3,300	200
Shintech	Plaquemine, LA	1,300	
Westlake PVC	Calvert City, KY	800	75
<b>Total</b>		<b>15,779</b>	<b>4,437</b>

\* includes VCM and PVC employment at both OxyVinyl Texas locations.

Source: SRI Consulting (Menlo Park, CA), CEH (Chemical Economics Handbook)  
Marketing Research Report: Polyvinyl Chloride (PVC) Resins (September, 2003).

We do not have separate employment data for VCM production; in cases of joint production at the same location, some VCM employment may be included in our PVC resin employment estimate. The Environment Canada study of chlorine-related industries (discussed early in this report in connection with the costs of alternatives) identifies one Canadian plant where 200 workers were producing VCM, with production of at least 4.71 million pounds per worker. If this ratio applied to US VCM production today, there would be about 3,700 workers making VCM at the 12 facilities shown in Table 16 (some of whom have already been included in our estimate of PVC resin workers). Again, this is, if anything, too high an estimate.<sup>137</sup>

Our estimates are therefore 5,600 or fewer workers producing PVC resin, and 3,700 or fewer workers making VCM, with an uncertain amount of double-counting between the two categories. In sum, the number of workers producing VCM and PVC resin is roughly 9,000 or less. These workers are only a small fraction of the much larger number of employees in chlorine-producing and chlorine-using plants in Table 15. In addition, as shown in Table 15, there are

roughly 126,000 workers at PVC fabrication plants. That is, most of the workers employed in PVC-related industries are fabricators, not VCM/PVC production workers.

### *Effects on PVC Workers*

A complete PVC phaseout will not happen overnight. But, over a period of years, it will change the jobs that are performed in our economy. Many workers will find themselves doing the same job with different materials; for example, the same products may be fabricated at the same plants, but out of different plastics. As the momentum builds for a PVC phaseout, the owners of fabrication plants will seek actively to keep up with the changing market.

In many cases, plants with the capacity to manufacture PVC products have the capacity to manufacture alternative products as well, although different equipment may be required. For example, the PVC Container Company manufactures plastic bottles from both PVC and polyethylene terephthalate (PET). According to a company representative, PVC and PET bottles are made with different equipment, but are manufactured at the

same facility.<sup>138</sup> In other cases, PVC products distributed within the US are fabricated overseas. For example, the medical gloves discussed in the section on medical supplies, above, are all manufactured in Asia. Omni International gloves are manufactured in countries including China, Malaysia, and Thailand; High Five gloves are manufactured in either China or Taiwan; and Kimberly Clark gloves are manufactured in Thailand.<sup>139</sup> Thus, switching among the glove types we have discussed here would apparently have no employment consequences within the US. We did not investigate the effect on employment in the producing countries; we did learn that gloves produced for Kimberly Clark are manufactured at a single plant, which has a separate production area for each glove material and employs different equipment for each type.

In the case of large PVC products, such as pipes, equipment requirements may differ for production using alternative materials. However, many companies produce or use a diversified set of plastics, so ceasing sales of PVC products would likely lead to a shift within the company, not putting the company go out of business. As mentioned above, for example, J-M Manufacturing has recently diversified to begin producing PE in addition to PVC pipe. Another interesting example is Westlake Chemical Corporation, a vertically integrated company that produces both VCM and PVC while also producing alternatives, including polyethylene. Westlake's fabricated products include both PVC and polyethylene pipe, among other products.<sup>140</sup> In a similar vein, CertainTeed Corporation produces a variety of PVC products, but also produces fiber cement siding, one of the promising alternatives to vinyl siding.<sup>141</sup> While the employment practices of such companies will vary from case to case, corporate diversification creates the possibility of retaining and reassigning workers when PVC is phased out.

Workers who make VCM and PVC resin would not necessarily be out of work if PVC is phased out: in many cases PVC will be replaced by other petrochemical products, such as non-chlorinated plastics or synthetic rubber, which may be made by the same companies or in the same communities that now make VCM and PVC. Thus there will be new jobs to be filled making the alternative materials, which current VCM and PVC workers could well perform.

At the same time, it is possible that some workers will not find jobs making the alternatives. Even if the old jobs are replaced with new ones, the labor market

does not automatically move the displaced workers into the new positions. The threat of some job turnover is not unique to the question of chemical phaseouts; rather, it occurs with any large-scale policy shift.

The changes that would result from a PVC phaseout are not large relative to the ongoing turnover of employment in the US economy. Jobs are constantly being eliminated, and other jobs created, in enormous numbers. In the 12-month period from August 2002 through July 2003, when total US employment decreased by 170,000 jobs, there were actually 48,150,000 new hires and 48,320,000 separations (quits, retirements, layoffs, and firings).<sup>142</sup> In manufacturing alone, which was particularly hard hit in the same period, losing just over a million jobs, there were 4,000,000 new hires and 5,020,000 separations. That is, in addition to the net loss of a million manufacturing jobs, there was turnover of another four million jobs—an average turnover of 11,000 manufacturing jobs per day, every day of the year. If every job in VCM and PVC resin production were replaced by a different job producing substitute materials in a different plant, this would amount to less than one day's average turnover of US manufacturing employment.

Nonetheless, the replacement of jobs in VCM and PVC production with jobs in other industries could impose a real burden on the affected workers (just as employment turnover of all sorts frequently does). If substitute materials are produced at the same or nearby locations, the displaced workers could be offered employment in the plants making the new materials; but this may not solve the entire problem. Providing protection and support for workers who lose their jobs is an inescapable problem of public policy, both for the small numbers who may be affected by health and environmental policies such as a PVC phaseout and for the much larger numbers who are affected by business-oriented "free trade" schemes, budget cutbacks, management errors, marketing failures, and other ongoing sources of turmoil in the market economy. One interesting and ambitious policy option for displaced workers, the Just Transition blueprint developed by a coalition of labor and environmental leaders, sounds utopian in the US political context, but is actually more modest than similar programs that exist in Europe today.<sup>143</sup>

## Steps Toward Alternatives

Many steps have already been taken in the direction of reducing and ultimately eliminating the use of PVC. In this final section we examine three areas where movement away from PVC can already be seen: public policy initiatives in the US and around the world; industry initiatives, including those by auto companies and other leading manufacturers; and a small sampling of the numerous "green building" initiatives in the US. In the first two areas, we rely heavily on an extensive review published by Greenpeace.

### *Policy Initiatives to Phase out PVC*<sup>144</sup>

Here we provide a brief overview of forward-looking policies, initiatives, and strategies that have been adopted by communities, governments, and professional organizations concerned about the health and environmental hazards associated with PVC production, use, and disposal. These efforts include laws, policy statements, strategic plans, and other government initiatives.

#### **US State and Municipal Policies**

A number of municipal governments in the US have adopted policies on PVC products. For example, Rahway, New Jersey, prohibits the use of PVC or polystyrene in retail food establishments, requiring the use of degradable packaging. Lake in the Hills, an Illinois town, has banned the use of PVC pipes in construction, due to a variety of practical and safety-related concerns, including worker exposure to glues and solvents during installation. In California, the city of Oakland and Marin County have passed resolutions encouraging the use of PVC-free materials and the use of PVC alternatives in health care institutions, with a long-term goal of phasing out PVC products from health care entirely. Glen Cove, New York, has banned PVC use in eating utensils or food containers in all city food retailers.

A number of states and municipalities have adopted policies on dioxin emissions, some of which include specific references to PVC. San Francisco, Oakland, and Berkeley, California have adopted resolutions to eliminate dioxin, including PVC use reduction as part of a broader strategy. The Rhode Island Department of Environmental Management has adopted a regulation to reduce PVC materials in the waste stream by 50 percent by 2003. New Hampshire has

adopted a policy to cut dioxin emissions; the policy specifically discusses use, disposal, and labeling of PVC. Boston has recently adopted a dioxin reduction purchasing resolution that could lead to a reduction in use of PVC products.

#### **Canada**

Canada has banned PVC in food packaging and has initiated a public awareness campaign to urge parents not to purchase such toys for small children. British Columbia has made a commitment to the long-term goal of encouraging hospitals to replace PVC with safer materials. The Toronto city government places restrictions on the disposal of PVC products.

#### **US Health Care Organizations**

A number of US health care institutions and professional societies of health care providers have adopted resolutions encouraging the elimination of PVC and other products that are important contributors to dioxin formation. The American Public Health Association (APHA) has adopted resolutions to phase out dioxin contributors in medical waste, including PVC products. The Chicago Medical Society, the California Medical Association, and the Minnesota Medical Association have adopted resolutions to investigate PVC alternatives as a means to reduce dioxin emissions from medical waste. The American Nurses' Association and the American Medical Women's Association recommend the reduction of dioxin emissions from medical waste. The member hospitals of the Maine Hospital Association have all committed to continuously reducing the use and disposal of PVC plastic, prioritizing disposable health care and office products as a first step.

The annual CleanMed conference brings together researchers, product vendors, health care purchasers, and others to exchange information on safer health care technologies and to promote the development of healthy markets in these products.<sup>145</sup>

#### **Europe**

Sweden was the first country to propose general restrictions on the use of PVC in 1995; restrictions have been enforced since 1999, and the country is working toward discontinuing all PVC uses.

Denmark created a policy in 1996 urging the phaseout of PVC use after the failure of a 1991 voluntary PVC recycling program. One local community in Denmark has restricted the sale of PVC and latex toys and has committed to the reduction of PVC use in hospitals and other institutions. Denmark's Grenaa Hospital has been a world leader in the elimination of PVC, having started a program to replace PVC with safer alternatives as early as 1988. Germany has banned the disposal of PVC in landfills as of 2005, is minimizing the incineration of PVC, and is encouraging the phaseout of PVC products that cannot easily be recycled. Since 1986 at least 274 communities in Germany have enacted restrictions against PVC. The government of the Netherlands has created a policy that requires the use of alternative products for those that have no feasible recycling or reuse system.

Spain's government created a goal in 1995 of reducing PVC packaging by 20 percent by 2000. A number of cities in Spain have developed restrictions on the use of particular PVC products. In addition, 62 cities in Spain have signed on to a "PVC free" agenda, which declares that they will phase out all PVC food packaging and discontinue use of PVC construction materials in government and governmentally funded buildings. In Austria, a number of regional governments have initiated policies that restrict the use of PVC. The capital of Luxembourg recommends that no new PVC piping shall be put in the sewage systems. In Norway, the capital city, Oslo, decided in 1991 to phase out use of PVC in all public buildings. A number of local governments in the United Kingdom have adopted policies to avoid use of PVC windows, and the community of Newhaven has adopted a policy to become entirely PVC free, unless PVC alternatives cannot be procured at a reasonable cost. The Czech Republic has adopted policies to ban the use of PVC food packaging after 2008.

In addition to the policies developed by countries and municipalities, public transportation and utility systems in many countries require the use of PVC-free materials. Public subway and rail systems in Austria, Germany, Spain, and the UK all prohibit the use of PVC cables. The German railways go one step further and avoid the use of any PVC materials. Additionally, water, sewer, and gas companies in the UK are also not using PVC pipes in new or replacement projects.

A number of regulatory initiatives have focused on PVC toys, due to the threat of harm to children if

they suck or chew on soft plastic toys. Certain PVC toys and other PVC products for small children have been banned in the European Union as a whole since 1999. Bans on the use of PVC for soft toys have been adopted in many European countries, as well as in other countries including Argentina, Mexico, the Philippines, Tunisia, and the Fiji Islands.

### Asia/Pacific

Japan passed a law requiring manufacturers to recycle all packaging material by 2000 in order to reduce dioxin emissions; in response, many manufacturers have switched to non-PVC packaging. Japan has also adopted a policy that limits the use of PVC sheathing in cables used in all governmental and public buildings. An ordinance was also amended to restrict the use of PVC containing toxic additives in cooking utensils and baby toys. Many cities in Japan have adopted, although not necessarily implemented, bans either on all PVC products or on particular PVC products. Singapore has legislated that PVC coated cables are hazardous waste and therefore bans their import under the Basel Convention on Hazardous Waste.

### Industry Initiatives<sup>146</sup>

Recognizing the health and environmental reasons to reduce PVC use, and the feasibility of alternatives, many industries—including some very big ones—have begun to shift away from PVC.

*Automobiles.* A number of car manufacturers have made strong commitments to reducing the use of PVC in their products, often citing environmental, health, and engineering reasons. European manufacturers have taken many steps in this direction. For example, Peugeot in France is reducing PVC use in the interior and exterior of its cars as a way to prevent recycling problems. A number of German car manufacturers have sharply reduced PVC use. Daimler-Benz stopped using PVC in underbody coating and in the interior of all cars as of 1995 and planned to ultimately phase out all PVC use. Opel, the European subsidiary of General Motors, and Mercedes Benz also do not use PVC in car interiors. BMW has adopted material specifications that express a preference for dashboard, trim, and wire coating materials other than PVC, and offers PVC-free dashboards.

Japanese car manufacturers have also taken concrete steps toward reducing PVC use. For example,

Daihatsu Motor Company has established a PVC reduction policy, reducing PVC use in instrument panel padding, roof linings, side moldings, side window linings, the soundproofing component of dashboards, and door trim. The company is investigating ways to reduce PVC use further in side windows, roof fabric, floor undercoating, and wire harness coating. Hino Motors is considering PVC alternatives in truck and bus interiors, exteriors, and wiring systems. Honda made a commitment to replacing PVC interiors by 2003. Mitsubishi is working to substitute PVC in instrument panels and door trim surfaces and already is using alternatives for roof linings and sheet materials. Nissan began using alternatives to PVC in cables in 1997 and is using PVC alternatives for instrument panels, door trim, and side guard moldings and harnesses. Suzuki Motor Corporation is increasing its use of substitutes for PVC, and Toyota has developed PVC alternatives for car interiors and bumpers.

In the US, the world's largest auto manufacturers have also committed to reducing PVC use. General Motors eliminated PVC from its interiors in 1999. The 2000 Pontiac Bonneville used a PVC-free material for the full instrument panel for the first time in North America. Ford has set the target of eliminating the use of PVC by the model year 2006 for all of its plants worldwide and is instructing its suppliers to design vehicles using more recycled content and plastics that are easy to recycle. A number of US auto suppliers have begun their own initiatives to remove PVC and have started by removing it from interior panels, instrument panels, integrating skin, substrate, reinforcing beams, and batteries.

*Food Packaging and Water Bottles.* The use of PVC in food packaging has been the source of considerable concern in Europe. PVC food packaging is no longer used in Austria, due to measures taken by Austrian supermarket chains in the early 1990s. Carlsberg Italia, the Italian unit of the Danish beer company, has discontinued its use of PVC caps. A number of water bottling companies in Europe have also stopped using PVC in their bottles, including Nestlé brands, Spa, and Evian. In Spain, thirty-six water bottling companies including Danone and Perrier are phasing out PVC.

In Brazil, the agricultural food manufacturer Cargill no longer uses PVC bottles for its Liza soybean oil brand. In Japan, Nihon Suisan Kaisha has converted to PVC-free packaging for its sausages, and Kagome Company has converted to PVC-free packaging for all household products.

In the US, Federated Group, Borden Cremora Non-Dairy Creamers, and Eagle Family Foods have converted to PVC-free packaging for their creamers; Dean Foods is replacing its milk containers with PVC-free packaging; VegiWash has eliminated the use of PVC in its fruit and vegetable wash bottles; and Planters has eliminated its use of PVC bottles for peanut oil.

*Hospital Initiatives.* Grenaa Central hospital in Denmark has phased out 95 percent of its PVC use. The Glanzing pediatric clinic in the Wilhelminen Hospital in Vienna became the first Neonatal unit in the world to announce in 2003 that it will cease to use PVC products for invasive uses, although some products for non-invasive uses do not yet have a PVC alternative.<sup>147</sup> Glanzing has also introduced PVC-free products in construction, as well as for overshoes, gloves, bed mattresses, and aprons.

In the US, Universal Health Services, the third largest hospital management company, and Tenet Healthcare Corporation, the second largest for-profit health care company, are actively looking to replace PVC medical supplies. Four medical supply purchasing organizations—Broadlane, Consorta Inc, Premier Inc, and Novation—have all committed to reducing the procurement of PVC products and have urged their members to do the same.<sup>148</sup>

The shift to PVC-free medical care products is facilitated by new technological developments. For example, the Japanese company Terumo has begun manufacturing PVC-free dialyzing fluid bags made from polypropylene and has developed a new polypropylene material for continuous ambulatory peritoneal dialysis; McGraw Inc supplies PVC-free IV bags in the US; and Saint-Gobain Performance Plastics has recently developed an alternative to PVC for medical tubing.<sup>149</sup>

*Shoes.* Nike began to phase out PVC in its products in 2001, and currently advertises several PVC-free footwear models. Nike's website showcases several PVC-free shoe brands, which are labeled with Nike's new environmentally sound logo.<sup>150</sup> Other manufacturers, including Adidas, Asics, and Puma, are also in the process of phasing out PVC in shoes.<sup>151</sup>

*Electronics.* Sony states in its 2003 *Corporate Social Responsibility Report* that the company is working to reduce PVC in all its products by the end of 2005.<sup>152</sup> Sony now has PVC-free headphone cords, speaker boxes, and disk drives on the market.<sup>153</sup> Recently, Sony released two products in the Tokyo market that

replace PVC with the corn-based polymer polylactic acid (PLA): a DVD player and AIBO, a robotic pet.<sup>154</sup> Toshiba is currently working to phase out the use of halogenated compounds, including PVC, from its circuit boards.<sup>155</sup>

*Furniture.* The Swedish furniture retailer IKEA, well-known across Europe and the United States, started phasing out PVC use in September of 1992. To date IKEA has eliminated PVC from all furniture, and plans to phase out PVC in its lamp wiring by 2006.<sup>156</sup>

*Retailing.* Marks and Spencer, one of the largest retailers in Great Britain, pledged in 2001 to phase out the use of PVC in its products, focusing initially on food packaging.<sup>157</sup>

### *Innovative Construction Projects*

There has been an explosion of interest in environmentally sound construction in the US in recent years. A wealth of information on green building initiatives, including many case studies of individual building projects, is available through the US Green Buildings Council. Initiatives showcased by the council address a range of environmental and health concerns, including energy efficiency, environmentally sound management of wastes, and creating buildings with good indoor air quality.<sup>158</sup>

The Healthy Building Network (HBN) provides a clearinghouse of information and contacts on PVC-free and other environmentally preferable building practices. HBN has also collected case studies of building initiatives that have used safe construction materials, including a number of health care institutions that have undertaken green building projects. To cite just one example, Beth Israel Medical Center in New York City completed a set of interior renovations in 2000. Among other steps to ensure environmental safety and protect indoor air quality, Beth Israel excluded PVC from its construction and furniture specifications.<sup>159</sup>

In this section, we highlight just a few of the growing number of innovative construction projects in which special efforts have been made to choose materials that are safe for human health and the environment, while keeping costs low. All of the examples discussed here have reduced or eliminated the use of PVC.

**GreenHOME**, a volunteer group, partnered with the Washington, DC chapter of Habitat for Humanity to

design and build a low-income home that is energy efficient and built from materials that are safe for human health and the environment.<sup>160</sup> The purpose of the project was to demonstrate that green building is not only an option for luxury homes; it is equally possible for home builders on a budget. After exhaustive research on materials, the group constructed a home whose total cost was \$75,000.

The GreenHOME house is not 100 percent free of vinyl, but the use of vinyl was kept to a minimum. The windows of the house are vinyl-clad wood and cost \$264 each. The siding is Hardiplank (a fiber cement product), purchased at \$0.55 per linear foot, for a total cost of \$2,534. For flooring, the project used salvaged wood floors for living room areas and natural linoleum for the kitchen. The total cost of flooring was \$4,221. For roofing, the material of choice was 100 percent recycled aluminum shingles, at a cost of \$1,464.

Another good model of green building on a budget is the **Erie Ellington Homes** project in Dorchester, Massachusetts.<sup>161</sup> Developed by the Codman Square Neighborhood Development Corporation with technical assistance provided by the Hickory Consortium (Bruce Hampton, AIA, architect), this project includes fifty high-energy-efficiency housing units. The builders used fiber cement clapboards instead of vinyl and high-quality recycled content aluminum clad wood windows instead of vinyl clad windows.

One goal of the project was to provide safe homes for children and adults with asthma, by avoiding building materials that are associated with air quality problems. Although not definitive, early results suggest that the project has had some success in this regard; interviews with new residents have shown that symptoms were noticeably reduced in 8 out of 18 asthma sufferers.

To save money, the project used vinyl composite tile in some public areas, such as common halls and stairs; these were selected as areas in which outgassing of phthalates would be least likely to affect occupants. For some other areas the project used alternative flooring products, including linoleum.

Both the Erie Ellington project and the GreenHOME project used Hardiplank, a durable fiber cement siding product that requires very infrequent painting. The GreenHOME project estimates that the Hardiplank siding will require painting "every 15 to 20 years, compared to every 5 to 10 years for wood



siding in the Washington, DC climate."<sup>162</sup> Managers of both projects seem to have been relatively satisfied with Hardiplank. The principal disadvantage of the material for the GreenHOME project, which relied largely on volunteer labor, is that Hardiplank is somewhat more difficult for volunteers to work with than vinyl. The project report notes that cutting the planks created large amounts of dust, so that volunteers had to wear filtration masks. Dust would have been reduced if the project had used special tools for cutting the Hardiplank, but these tools were out of the price range of the project. In addition, because it is more dense than wood, the Hardiplank siding was more difficult to nail into place than wood siding would have been. The GreenHOME project report concludes that overall, "these problems were minor and acceptable."<sup>163</sup>

The **Sheraton Rittenhouse Square Hotel** in Philadelphia advertises itself as an "environmentally smart hotel."<sup>164</sup> The hotel has wallpaper with a water-based finish instead of vinyl wall coverings. Carpeting in the hotel does not have a PVC base. For flooring in non-carpeted areas, the hotel has used natural linoleum instead of vinyl tile. The hotel plumbing includes no PVC pipe.

Barry Dimson, co-owner of the hotel, has made the economic case for building environmentally sound hotels in a series of articles. He argues that up-front costs for building an environmentally sound hotel, using safe building materials, are not significantly different from the cost of building a "traditional"

hotel, where air quality may be poor due to mold and off gassing from PVC and other building materials. Dimson notes that an estimated 20 percent of total project cost in the construction of a new hotel is land acquisition, and around 55 percent is "the 'hard' cost of construction, with 'soft' costs such as carrying charges and design fees comprising the remaining 25 percent." If half of the "hard cost" of construction is dedicated to excavation, foundations, and superstructure, then just half the construction cost is dedicated to "the building's 'skin,' mechanical equipment, [and] building materials." This 27.5 percent is the portion that is affected by green building considerations. Thus, argues Dimson, "even if [green building materials] cost 10 percent more up front, 10 percent of 27.5 percent represents a premium of [just] 2.75 percent over the total cost."<sup>165</sup>

Green building was prioritized in construction of a new building for **Adat Shalom**, a synagogue in Bethesda, Maryland.<sup>166</sup> Among other choices, the community chose to use cork instead of vinyl flooring wherever possible. Since finishing construction of the new building, members of Adat Shalom have been working with others to spread knowledge of best practices for green buildings in religious communities. The "Building in Good Faith" initiative, launched by filmmaker Judith Helfand and religious leaders, asks faith-based institutions to reduce their purchasing and use of toxic building materials, particularly those made from PVC.<sup>167</sup>

## Conclusion

PVC has become universal, used in every area of modern life. It is said to be cheap, convenient, safe, and maintenance free. Our review of the evidence finds that the advantages of PVC are often overstated—it is a little cheaper than the alternatives in some areas, but no bargain at all in others. Our analysis offers four categories of responses to the economic argument for PVC:

- It is not always cheaper on a life-cycle cost basis, as in flooring.
- The alternatives will become cheaper over time, due to economies of scale and learning curve effects.
- The use of PVC products often poses health and safety hazards, as in medical supplies.
- The costs of environmental protection and improvement are routinely overstated in advance.

In our look at specific markets, we found that less toxic alternatives are successfully competing with PVC in many pipe applications, in single-ply roofing, in flooring on a life-cycle cost basis, and in medical supplies due to growing concerns about the health hazards of PVC. In siding and windows, among the fastest-growing vinyl markets of recent years, promising new alternatives have appeared.

The employment effects of a transition to alternative materials may be modest. PVC will be replaced by other materials that also require labor; workers will still be needed to make the substitute products. In some cases, the same factories and workers may fabricate the same products from new materials.

There are policy initiatives at every level, internationally and within the US, calling for reduction and restriction of PVC use. Major industries are beginning to substitute less toxic materials for PVC throughout their product lines. The rapidly growing “green building” movement has created numerous successful examples of the use of safer alternatives materials; the few examples described here are only a sample of the encouraging diversity of approaches emerging in the construction industry today.

Our review of PVC uses and alternatives makes it clear that a PVC phaseout is achievable and affordable. The alternatives are increasingly well known and well developed, and in many cases are already cost-competitive with PVC. It is realistic and practical to build health and environmental considerations into materials choice for municipal infrastructure, commercial and residential building, medical supplies, and consumer products. The cost impacts of substitution will be modest, and will grow smaller over time.

## Endnotes

<sup>1</sup> For an overview of PVC's history, see Peter H. Spitz, *Petrochemicals: The Rise of an Industry* (New York: John Wiley and Sons, 1988).

<sup>2</sup> For an overview of current information and references on health hazards associated with PVC production, use, and disposal, see the affidavit of Judith Schreiber, PhD, Senior Public Health Scientist, New York State Office of the Attorney General, provided to the Supreme Court of the State of New York, In the Matter of the Application of Resilient Floor Covering Institute and Tarkett, Inc. vs. New York State Department of Environmental Conservation, Index Number 6721-02, May 9, 2003, available at <http://www.healthybuilding.net/documents/Affidavit-of-Judith-Schreiber-Ph-D.pdf>, viewed December 2003. Our review draws on the summary provided by Schreiber and references therein. Also see Joe Thornton, *Pandora's Poison: Chlorine, Health, and a New Environmental Strategy* (Cambridge, MA: MIT Press, 2000). ←

<sup>3</sup> US Department of Health and Human Services, Public Health Service, National Toxicology Program, *Report on Carcinogens, Tenth Edition* (December 2002), available at <http://ehp.niehs.nih.gov/roc/toc10.html>, viewed November 2003. Also see US Environmental Protection Agency, "Vinyl Chloride Hazard Summary" (2002) and International Agency for Research on Cancer International Agency for Research on Cancer, "Overall evaluations of carcinogenicity: An updating of IARC monographs, Volumes 1 to 42," *IARC Monographs on the Evaluation of Carcinogenic Risks to Humans, Supplement 7*, (Lyon, France: IARC, 1987), pp. 373-376, cited in Schreiber 2003. ←

<sup>4</sup> On routes of human exposure to vinyl chloride, see Agency for Toxic Substances and Disease Registry (ATSDR), *Toxicological Profile for Vinyl Chloride* (September 1997, CAS # 75-01-4), p. 153ff, available at <http://www.atsdr.cdc.gov/toxprofiles/tp20.html>, viewed December 2003.

<sup>5</sup> See the literature review in ATSDR 1997, pp. 54-60, and studies cited in Schreiber 2003, point 12.

<sup>6</sup> See C. Maltoni, "Two Cases of Liver Angiosarcoma among PVC Extruders of an Italian Factory Producing PVC Bags and Other Containers," *American Journal of Industrial Medicine* 5: 297-302 (1984); J. Kielhorn, "Vinyl Chloride: Still a Cause for Concern," *Environmental Health Perspectives* 108:7 (2000); and R. H. Wong, "An increased mortality ratio for liver cancer among polyvinyl chloride workers in Taiwan," *Occupational and Environmental Medicine* 59 (2002), 405-409, all cited in Schreiber 2003.

<sup>7</sup> See Schreiber 2003, points 17 and 18.

<sup>8</sup> On use and health effects of PVC additives, see Schreiber 2003, points 21-25. On use of plasticizers in medical equipment, also see Joel Tickner, "The Use of Di-2-Ethylhexyl Phthalate in PVC Medical Devices: Exposure, Toxicity, and Alternatives," (University of Massachusetts Lowell: Lowell Center for Sustainable Production, no date).

<sup>9</sup> See our later sections on flooring and on medical supplies for additional discussion of plasticizer exposure through these routes.

<sup>10</sup> See National Toxicology Program and Center for the Evaluation of Risks to Human Reproduction, *NTP-CERHR Expert Panel Report on Di(2-ethylhexyl) phthalate* (NTP-CERHR-DEHP-00) (October 2000), available at <http://cerhr.niehs.nih.gov/news/phthalates/DEHP-final.pdf>, viewed December 2003.

<sup>11</sup> See Jouri J. K. Jaakola et al., "Interior Surface Materials in the Home and the Development of Bronchial Obstruction in Young Children in Oslo, Norway," *American Journal of Public Health* 89:2 (February 1999), 188-192.

<sup>12</sup> See Schreiber 2003, point 35. Also see Robert F. Dyer and Victor H. Esch, "Polyvinyl Chloride Toxicity in Fires: Hydrogen Chloride Toxicity in Fire Fighters," *Journal of the American Medical Association* 235 no. 4 (1976), pp.393-397; Jeffrey S. Markowitz, Elane M. Gutterman, Sharon Schwartz, Bruce Link, and Sheila M. Gorman, "Acute Health Effects Among Firefighters Exposed to a Polyvinyl Chloride (PVC) Fire," *American Journal of Epidemiology* 129 no. 5 (1989), pp.1023-1031. ←

<sup>13</sup> See Thornton 2000, especially pp. 271, 276, and 316-319, and references therein. Also see Schreiber 2003, point 30.

<sup>14</sup> All figures in this paragraph are calculated from Eric Linak with Kazuo Yagi, "Polyvinyl Chloride (PVC) Resins," Chemical Economics Handbook Marketing Research Report (Menlo Park, CA: SRI International, September, 2003).

<sup>15</sup> International Joint Commission, "A Strategy for Virtual Elimination of Persistent Toxic Substances" (Windsor, Ontario, 1993).

<sup>16</sup> Hickling Corporation, "Economic Instruments for the Virtual Elimination of Persistent Toxic Substances in the Great Lakes Basin," report to International Joint Commission (Windsor, Ontario, 1994).

<sup>17</sup> Charles River Associates, Inc., "Assessment of the Economic Benefits of Chlor-Alkali Chemicals to the United States and Canadian Economy" (Boston, 1993).

<sup>18</sup> Environment Canada, "A Technical and Socio-Economic Comparison of Options to Products Derived from the Chlor-Alkali Industry" (1997).

<sup>19</sup> The adjustment is that Table 2 omits Hickling's data on windows; Hickling estimated that implausibly large savings were available from replacing PVC windows with aluminum windows. Thus our adjustment increased the Hickling cost estimate for replacing PVC.

<sup>20</sup> These are purely hypothetical numbers for illustrative purposes, not real data. In reality, of course, ceramic plates often last much more than a year, increasing their attractiveness relative to paper plates.

<sup>21</sup> LCAs frequently emphasize energy use, carbon dioxide emissions, and criteria pollutants, since these categories are often better documented than toxic emissions. For a comparative analysis of recent LCA studies of PVC, highlighting their differences in data coverage, see Eric Copius Peereboom, Rene Kleijn, Saul Lemkowitz, and Sven Lundie, "Influence of Inventory Data Sets on Life-Cycle Assessment Results: A Case Study on PVC," *Journal of Industrial Ecology* 2 no. 3 (1999), pp. 109-130.

<sup>22</sup> *Tellus Institute Packaging Study* (Boston: Tellus Institute, 1992). For a brief overview of this massive study, see Frank Ackerman, *Why Do We Recycle? Markets, Values, and Public Policy* (Washington DC: Island Press, 1997), Chapter 5.

<sup>23</sup> For detailed formulae used to calculate learning curve effects, see the "Learning Curve Calculator," available at <http://www.jsc.nasa.gov/bu2/learn.html> (viewed February, 2003). On the economic theory of learning curves, see, for example, A. Michael Spence, "Investment Strategy and Growth in a New Market," *The Bell Journal of Economics* 10 no. 1 (Spring, 1979), pp. 1-19; Steven Klepper and Elizabeth Graddy, "The Evolution of New Industries and the Determinants of Market Structure," *The RAND Journal of Economics* 21 no. 1 (Spring, 1990), pp. 27-44; and Pankaj Ghemawat and A. Michael Spence, "Learning Curve Spillovers and Market Performance," *Quarterly Journal of Economics* 100 Supplement (1985), pp. 839-852.

<sup>24</sup> In that period, cumulative production of the Model T went from less than 20,000 to about 7 million cars, doubling more than eight times. W. J. Abernathy and K. Wayne, "Limits of the Learning Curve," *Harvard Business Review* 52 no. 5 (1974), pp. 109-119.

<sup>25</sup> Brian W. Arthur, an economist at the Santa Fe Institute, has argued that many of society's important economic and technological choices are "path dependent." A technology that, perhaps accidentally, gains a slight lead early in its history may be able to solidify that lead by gaining market share and lowering prices, "locking out" other technologies that may be equally or more efficient if adopted on a large scale. The Windows operating system, the standard videocassette format, the dominant nuclear reactor design, and the gasoline-powered automobile engine, for example, all started with only small leads over equally (or more) attractive rival technologies; all have come to be "locked in" and dominate their markets through the path-dependent process that Arthur describes. See Brian W. Arthur, *Increasing Returns and Path Dependence in the Economy* (Ann Arbor: University of Michigan Press, 1994).

<sup>26</sup> Our calculation from the graph in Peter H. Spitz, *Petrochemicals: The Rise of an Industry* (New York: John Wiley and Sons, 1988), p. 415. Spitz presents separate graphs of cumulative production vs. price for PVC and copolymers, for value added by polymerizer, and for vinyl chloride monomer. In these three graphs, a doubling of cumulative production is associated with price declines of 34 percent, 31 percent, and 40 percent, respectively.

<sup>27</sup> Spitz (1988), pp. 390-417.

<sup>28</sup> See Joel Tickner (no date).

<sup>29</sup> US Food and Drug Administration, "FDA Public Health Notification: PVC Devices Containing the Plasticizer DEHP," (July 12, 2002), available at <http://www.fda.gov/cdrh/safety/dehp.html> (viewed September, 2003).

<sup>30</sup> For a survey of toy manufacturers' actions on PVC toys, see the Greenpeace Toy Report Card, available at <http://greenpeaceusa.org/bin/view.fpl/7434/article/287.html> (viewed November, 2003).

<sup>31</sup> See US Consumer Product Safety Commission, "Re: Petition Requesting Ban of Use of Polyvinyl Chloride (PVC) in Products Intended for Children Five Years of Age and Under," letter to National Environmental Trust and other groups (February 26, 2003), available at <http://www.cpsc.gov/LIBRARY/FOIA/FOIA03/petition/Ageunder.pdf> (viewed November, 2003).

<sup>32</sup> "Hazardous Materials: Polyvinyl Chloride," International Association of Fire Fighters, AFL-CIO, CLC (Washington DC, 1995). For a detailed literature review of health impacts of PVC, including combustion impacts, see the affidavit of Judith Schreiber before the Supreme Court of the State of New York in the matter of *Resilient Floor Covering Institute v. New York State Department of Environmental Conservation* (2003), available at [http://www.healthyliving.net/pvc/NYS\\_vinyl\\_affidavit\\_js.pdf](http://www.healthyliving.net/pvc/NYS_vinyl_affidavit_js.pdf) (viewed September, 2003).

- <sup>33</sup> Robert F. Dyer and Victor H. Esch, "Polyvinyl Chloride Toxicity in Fires: Hydrogen Chloride Toxicity in Fire Fighters," *Journal of the American Medical Association* 235 no. 4 (1976), pp.393-397; Jeffrey S. Markowitz, Elaine M. Gutterman, Sharon Schwartz, Bruce Link, and Sheila M. Gorman, "Acute Health Effects Among Firefighters Exposed to a Polyvinyl Chloride (PVC) Fire," *American Journal of Epidemiology* 129 no. 5 (1989), pp.1023-1031.
- <sup>34</sup> Dyer and Esch (1976).
- <sup>35</sup> "Expanded Inspections Needed To Assess Wiring Woes, Experts Say," *Aviation Today* special report (May 25, 1998), available at <http://www.aviationtoday.com/reports/wiring7.htm> (viewed October, 2003).
- <sup>36</sup> Edward Block, airplane wiring expert and former Pentagon consultant, personal email correspondence, available at <http://www.geocities.com/Eureka/Concourse/7349/wire.html> (viewed October, 2003).
- <sup>37</sup> Project on Government Oversight, "Fact Sheet on Aircraft Wiring Problems" (2000), available at <http://www.pogo.org/p/contracts/ca-021102-wiring.html> (viewed October, 2003).
- <sup>38</sup> Darren Huese, "Tinker tackles aging wiring systems," Oklahoma City Air Logistics Center Public Affairs, available at <http://www.afmc.wpafb.af.mil/HQ-AFMC/PA/news/archive/2001/jan/Tinkerwiring.htm> (viewed October, 2003).
- <sup>39</sup> *Aviation Today* special report (May 25, 1998).
- <sup>40</sup> US Congress, Office of Technology Assessment (OTA), *Gauging Control Technology and Regulatory Impacts in Occupational Safety and Health* OTA-ENV-635 (Washington, DC: US Government Printing Office, September 1995), p.89.
- <sup>41</sup> Hart Hodges, "Falling Prices: Cost of Complying With Environmental Regulations Almost Always Less Than Advertised," Economic Policy Institute (1997) (<http://epinet.org>); Winston Harrington, Richard D. Morgenstern, and Peter Nelson, "On the Accuracy of Regulatory Cost Estimates," *Journal of Policy Analysis and Management* 19 no. 2 (Spring 2000), pp.297-322.
- <sup>42</sup> Cheminfo Services, *A Retrospective Evaluation of Control Measures for Chlorinated Substances (Case Studies of Ex-Ante/Ex-Post Socioeconomic Effects)*, report to Environment Canada and Ontario Ministry of Energy, Science and Technology (March, 2000).
- <sup>43</sup> See Lisa Heinzerling, "Regulatory Costs of Mythic Proportions," *Yale Law Journal* 107 no. 7 (May, 1998), pp.1981-2070; Lisa Heinzerling and Frank Ackerman, "The Humbugs of the Anti-Regulatory Movement," *Cornell Law Review* 87 no. 2 (January, 2002), pp.648-670.
- <sup>44</sup> See Frank Ackerman and Rachel Massey, "Prospering With Precaution" (2002), available at [http://www.ase.tufts.edu/gdae/policy\\_research/PrecautionAHTAug02.pdf](http://www.ase.tufts.edu/gdae/policy_research/PrecautionAHTAug02.pdf); and Eban Goodstein, *The Trade-Off Myth: Fact and Fiction about Jobs and the Environment* (Washington, DC: Island Press, 1999).
- <sup>45</sup> These three sections were prepared with the assistance of Gail Vittori of the Center for Maximum Potential Building Systems in Austin, Texas. For comprehensive listings of alternatives to vinyl flooring and other construction materials, see the website of the Healthy Building Network, at <http://www.healthybuilding.net/pvc/alternatives.html> (viewed November, 2003).
- <sup>46</sup> Thanks to Jamie Harvie of the Institute for a Sustainable Future in Duluth, Minnesota for reviewing and commenting in detail on material presented here.
- <sup>47</sup> Keith Christman, Vinyl Institute, "Vinyl Use in Building and Construction," Vinyl Material Council Newsletter (May, 2003), available at [http://www.aamanet.org/pdf\\_files/Council\\_News\\_pdfs/VMC\\_Newsletter\\_May\\_03.pdf](http://www.aamanet.org/pdf_files/Council_News_pdfs/VMC_Newsletter_May_03.pdf).
- <sup>48</sup> Qualitative information on pipe materials is drawn from sources including Environment Canada 1997 and Jamie Harvie with Tom Lent, "PVC-Free Pipe Purchasers' Report," [http://www.healthybuilding.net/pvc/pipes\\_report.html](http://www.healthybuilding.net/pvc/pipes_report.html) (viewed December, 2003).
- <sup>49</sup> This section relies heavily on the Plastics Pipe Institute (PPI) website, <http://plasticpipe.org>, and on personal communication from Rich Gottwald, president of PPI, September-October 2002.
- <sup>50</sup> Plastics Pipe Institute, "2001 Statistics: North American Shipments of Polyethylene & Crosslinked Polyethylene Pipe, Tube & Conduit".
- <sup>51</sup> Daniel O'Connor, J-M Manufacturing, personal communication (September 2003).
- <sup>52</sup> See <http://www.usinspect.com/PBPlumbing/PBBackground.asp>.
- <sup>53</sup> See "Project Profiles: Indianapolis Water Company's Successful Transition to HDPE Pipe Marks Turning Point for Industry," available at [http://www.isco-pipe.com/isco/project\\_profiles/indy\\_water\\_01.asp](http://www.isco-pipe.com/isco/project_profiles/indy_water_01.asp), viewed November 2003.
- <sup>54</sup> Information on pipe materials used by United Water in New York and New Jersey was provided by Ron Seligmuller, Purchasing Department, United Water, personal communication, August 2002.
- <sup>55</sup> Steve D. Sandstrum, "Case Studies in High Density Polyethylene (HDPE) Water Distribution Systems," presentation to American Water Works Association Annual Conference (2003), available at

<http://www.plasticpipe.org/pdf/pubs/case/THUR2-6.pdf>. Sandstrum is a manager at BP Solvay Polyethylene North America.

<sup>56</sup> Boston Water and Sewer Commission, personal communication (July 2003).

<sup>57</sup> Robert Socolow, editor, "Fuels Decarbonization and Carbon Sequestration: Report of a Workshop", Princeton University Center for Energy and Environmental Studies Report No. 302, September 1997, pp.35-36 (<http://mae.princeton.edu/people/faculty/socolow/R302webfinal.pdf>, viewed December 2003).

<sup>58</sup> Two PVC cement products reviewed by the Center for Maximum Potential Building Systems (CMPBS) had relatively high volatile organic compounds (VOC) levels of 600 g/l and 760 g/l. According to CMPBS, many PVC cement products are made from tetrahydrofuran (THF) and cyclohexane; manufacturers of THF recommend varying exposure limits, in one case as low as 25 parts per million for an 8- and 12-hour time-weighted average; and individuals with preexisting diseases of the lungs or liver may have increased susceptibility.

<sup>59</sup> "Safety And Health Activists, Environmentalists And Unions Win Ban on Plastic Pipe in New York State," *NYCOSH Update on Safety and Health* (January 14, 2002), available at [http://www.nycosh.org/Update12\\_Jan-Mar\\_2002.html](http://www.nycosh.org/Update12_Jan-Mar_2002.html).

<sup>60</sup> For example, Joseph Zicherman of the consulting firm Fire Cause Analysis concludes a detailed review of flammability concerns involving plastic pipes by saying, "if proper installation detailing is observed, plastic piping installations present no greater fire risk than other types of piping materials available on the market today." See Joseph Zicherman, "Plastic Pipe and Fire Safety," available at <http://www.ppfahome.org/pdf/safety.pdf>.

<sup>61</sup> John Rattenbury, "Cast Iron vs. PVC: How Much Would You Pay for Quieter Pipes?," *PM Engineer Magazine* (August, 2000).

<sup>62</sup> Thanks to Gail Vittori and Monica Brown of the Center for Maximum Potential Building Systems in Austin, Texas, for the Austin case study and plumbing price comparisons.

<sup>63</sup> See, for example, <http://BuildersWebSource.com>, which compares copper and CPVC plumbing, concluding that if installed properly, "copper plumbing can last the life of the structure with little maintenance and overall long-term life-cycle savings."

<sup>64</sup> Jamie Harvie, P.E., personal communication (October, 2003).

<sup>65</sup> Total US roofing industry sales, including repairs and maintenance, were \$30.2 billion in 2001: Olicia Hinojosa and Karen Kane, "A Measure of the Industry," *Professional Roofing* (April, 2002).

<sup>66</sup> Kevin Aylwin, Payton Construction, personal communication (May, 2003). Tufts building personnel referred us to Payton Construction for answers to questions about the university's roofing choices.

<sup>67</sup> Figure 2 shows a relatively low lifetime for built-up asphalt roofs, although Tufts University selected this roofing type in part for its longevity. The resolution of the apparent paradox is that the data in Figure 2 are averages including roofs with different numbers of plies. Roofs with more plies, such as those at Tufts, will have longer lives.

<sup>68</sup> Ray Corbin, "Urban Heat Islands," *Roofing Contractor* (October, 2001).

<sup>69</sup> Comments by Dr. William Miller, as described in David Roodvoets, "SPRI," *Roofing Contractor* (May, 2003 supplement). "SPRI" refers to the Single-Ply Roofing Institute.

<sup>70</sup> Northcoast Commercial Roofing Systems representative, personal communication.

<sup>71</sup> Myer J. Rosenfeld, "An Evaluation of Polyvinyl Chloride (PVC) Single-Ply Membrane Roofing Systems," US Army Corps of Engineers Technical Report M-284 (March, 1981), available at <http://www.rci-mercury.com>.

<sup>72</sup> David M. Bailey, Stuart D. Foltz, Walter J. Rossiter Jr., and James A. Lechner, "Performance of Polyvinyl Chloride (PVC) Roofing: Results of a Ten-Year Field Study," *Proceedings of the Fourth International Symposium on Roofing Technology* (September, 1997), available at <http://www.rci-mercury.com>.

<sup>73</sup> The source for the Austin case study is Todd Hewitt, an associate of Fifth Wall Roofing (<http://www.fifthwallroofing.com/>), an Austin Green Building Program roofing contractor; information provided to Center for Maximum Potential Building Systems.

<sup>74</sup> Information on the Chicago project was supplied by the Center for Maximum Potential Building Systems.

<sup>75</sup> Public summaries of open bidding for roof replacement at the Longmeadow High School, Longmeadow, MA (December, 2001), and for the Bellamy Middle School, Chicopee, MA (March, 2002); copies on file with authors.

<sup>76</sup> The source for this section, unless otherwise noted, is research done by the Center for Maximum Potential Building Systems (CMPBS).

<sup>77</sup> *Floor Covering Weekly*, "Statistical Report 2002."

<sup>78</sup> Terry Bessire of Intertech Flooring, Austin, TX, personal communication.

<sup>79</sup> Jouri J. K. Jaakola et al., "Interior Surface Materials in the Home and the Development of Bronchial Obstruction in Young Children in Oslo, Norway," *American Journal of Public Health* 89:2 (February 1999), 188-192.

<sup>80</sup> These are described at [www.expanko.com](http://www.expanko.com).

<sup>81</sup> California Department of Health Services, Indoor Air 96..

<sup>82</sup> DCHA Green Materials Guide, page 1, CMPBS (September, 2002).

<sup>83</sup> See [www.stratica.com](http://www.stratica.com) for more information.

<sup>84</sup> The Occupational Health and Safety Administration notes that "A major ingredient used in manufacturing synthetic rubber and resin, 1,3-butadiene, has been found to cause cancer in laboratory rodents." See [http://www.osha.gov/dts/hib/hib\\_data/hib19840411.html](http://www.osha.gov/dts/hib/hib_data/hib19840411.html).

<sup>85</sup> Data were provided by Terry Bessire, Intertech Flooring (Austin, TX), Kim Pexton, Jim G. Davis Construction Corporation, Lesa Green, Turner Construction Company (Washington, DC) personal communication (September, 2003), and Gail Bothwick, Farr Associates (Chicago, IL) personal communication (September, 2003) to Center for Maximum Potential Building Systems.

<sup>86</sup> That is, referring to the column headings in Table 10, the ratio  $[D / (C+D)] > 0.98$  for every material shown.

<sup>87</sup> "Implementation Assessment for Maintenance Free Decking," memorandum prepared for the Under Secretary of the Navy by the Commander, Naval Supply Systems Command (January 14, 2000).

<sup>88</sup> For example, according to information gathered by the Center for Maximum Potential Building Systems, Armstrong's residential flooring is coated with a factory urethane finish, which cannot be buffed, whereas Armstrong recommends a wax finish for commercial flooring.

<sup>89</sup> For example, GlossTek 100, manufactured by Windsor Industries ([www.windsorind.com](http://www.windsorind.com), viewed November 2003), does not require stripping; the company's promotional literature claims up to 43-45% savings in floor maintenance costs.

<sup>90</sup> See [www.floorexpert.com](http://www.floorexpert.com). Search for Technique No. 19: Linoleum-Wet vs. Dry Maintenance (November, 2001).

<sup>91</sup> Information for this case study was provided by Terry Bessire of Intertech Flooring (Austin, TX) as related by Rick Early, Asst Director of UT/Austin's Division of Housing & Food Service, to Center for Maximum Potential Building Systems (CMPBS).

<sup>92</sup> Information for this case study was provided by Kim Pexton of Jim G. Davis Construction Corporation, personal communication (2003).

<sup>93</sup> Information for this case study was provided by Gail Borthwick of Farr Associates, personal communication (September 2, 2003).

<sup>94</sup> The "other" category in Table 1, which includes medical supplies, represents about 2 percent of PVC use; however, it also includes inventory changes, which could be negative, making the size of medical supplies ambiguous. Earlier versions of the same data source reported "other" uses, including medical supplies, without inventory changes, making it clear that medical uses of PVC were less than 3 percent of the total.

<sup>95</sup> In 2002 the US Food and Drug Administration (FDA) issued an advisory recommending that health care institutions work to reduce patients' exposure to the widely used plasticizer DEHP due to concerns about its effects on the developing male reproductive system. See US Food and Drug Administration, "FDA Public Health Notification: PVC Devices Containing the Plasticizer DEHP," (July 12, 2002), available at <http://www.fda.gov/cdrh/safety/dehp.html> (viewed September, 2003). On incineration of PVC medical waste and formation of dioxins and other persistent pollutants in medical incinerators, see Thornton 2000, pp. 268, 278-9, 283ff, and 317.

<sup>96</sup> Health Care Without Harm, "Alternatives to Polyvinyl Chloride (PVC) and Di-2-Ethylhexyl Phthalate (DEHP) Medical Devices," In *Going Green: A Resource Kit for Pollution Prevention in Health Care* (October 15, 2001 version), available at <http://www.noharm.org>.

<sup>97</sup> Landstingsförbundet (Federation of Swedish County Councils), *PVC in the Swedish Healthcare System: Current Applications and New Alternatives* (Stockholm: Landstingsförbundet, 2001).

<sup>98</sup> Mark Rossi, *Neonatal Exposure to DEHP and Opportunities for Prevention* (Falls Church, VA: Health Care Without Harm, October 2000, revised June 2001).

<sup>99</sup> Albert Rego and Lorraine Roley, "In-use Barrier Integrity of Gloves: Latex and Nitrile Superior to Vinyl," *American Journal of Infection Control* 27 no. 5 (October, 1999). The Universal Precautions published by the Centers for Disease Control in 1987 emphasized the need for health care workers to treat all patients as potentially infected with HIV or other blood-borne diseases and to use gloves and other protective gear accordingly. See Centers for Disease Control, "Recommendations for prevention of HIV transmission in health-care settings," *Morbidity and Mortality Weekly Report* 36 supplement no. 2S (1987), available at <http://www.cdc.gov/mmwr/preview/mmwrhtml/00023587.htm>.

<sup>100</sup> For overviews of the concerns associated with use of latex medical supplies and proposals for eliminating latex hazards in health care institutions see Philip B. Kellett, "Latex Allergy: A Review," *Journal of Emergency Nursing* 23 (1997), pp.27-36; also see Kristi K. Miller and Page Weed, "The Latex Allergy Triage or Admission Tool: an

Algorithm to Identify which Patients would Benefit from 'Latex Safe' Precautions," *Journal of Emergency Nursing* 24 (1998), pp.145-52. As many as 70 percent of anaphylactic reactions in children who have been anesthetized for surgery are thought to be caused by latex allergy; see F. Porri et al., "Association between Latex Sensitization and Repeated Latex Exposure in Children," *Anesthesiology* 86 no. 3 (March, 1997), pp.599-602. On the economic rationale for protecting health care workers by creating a latex-safe environment, see V.L. Phillips et al., "Health Care Worker Disability Due to Latex Allergy and Asthma: a Cost Analysis," *American Journal of Public Health* 89 no. 7 (July, 1999), pp.1024-1028. In an examination of three health care facilities of different sizes, this study finds that institutions are likely to benefit financially by creating a latex-safe environment, thus avoiding the high costs of illness and disability that can result from latex allergy.

<sup>101</sup> For toxicity and exposure information on acrylonitrile, see Agency for Toxic Substances and Disease Registry (ATSDR), "ToxFAQs for Acrylonitrile," CAS # 107-13-1 (July, 1999), available at <http://www.atsdr.cdc.gov/tfacts125.html> (viewed July, 2003).

<sup>102</sup> See US Department of Labor Occupational Safety and Health Administration, "Technical Information Bulletin: Potential for Allergy to Natural Rubber Latex Gloves and other Natural Rubber Products," (April 12, 1999), available at [http://www.osha.gov/dts/tib/tib\\_data/tib19990412.html](http://www.osha.gov/dts/tib/tib_data/tib19990412.html).

<sup>103</sup> Food and Drug Administration, "Guidance for Industry and FDA—Medical Glove Guidance Manual" (July 30, 1999), available at <http://www.fda.gov/cdrh/manual/glovman1.pdf> (viewed October 22, 2003).

<sup>104</sup> Information on this test is from Sustainable Hospitals Project, "Selecting Medical Gloves," fact sheet available at [http://www.sustainablehospitals.org/HTMLSrc/IP\\_Latex\\_GloveFacts.html](http://www.sustainablehospitals.org/HTMLSrc/IP_Latex_GloveFacts.html) (viewed October, 2003).

<sup>105</sup> Rego and Roley (1999).

<sup>106</sup> Notably, the brand with the highest out-of-box failure rate is not the same as the brand with the highest failure rate after use. Thus, the high average failure rates cannot be attributed to a localized problem in a single brand.

<sup>107</sup> Rego and Roley (1999).

<sup>108</sup> Catherine Galligan, Sustainable Hospitals Project, University of Massachusetts Lowell, personal communication.

<sup>109</sup> Kathy Gerwig, Director, Environmental Stewardship and National Environmental Health and Safety, Kaiser Permanente, personal communication (November, 2002).

<sup>110</sup> Anonymous, "EPP Success Story: Kaiser Permanente," *Environmentally Preferable Purchasing News for Health Care Organizations* 2 no. 3 (May, 2000).

<sup>111</sup> Fisher Scientific sales staff, personal communication (July, 2003). Bulk prices were obtained using an existing Tufts University account number on file with Fisher Scientific. The gloves on which we gathered information were provided to Fisher Scientific by manufacturers High Five, Kimberly Clark, and Omni.

<sup>112</sup> According to manufacturer information, the Accepted Quality Level (AQL) for leaks is 2.5 for vinyl gloves, meaning that up to 2.5 percent of the gloves may leak, whereas the AQL for the vinyl and nitrile gloves is 1.5.

<sup>113</sup> See Kimberly-Clark, "All FAQs: Medical Gloves—Testing—Barrier," available at <http://www.kchealthcare.com/LrnFAQsQandA.asp?id=891&CategoryName=Medical%20Gloves%20-%20Testing%20-%20Barrier> (viewed November, 2003).

<sup>114</sup> For the gloves that Fisher Scientific sales staff identified as broadly comparable, the latex gloves are the most expensive option. Some sources report substantially lower prices for latex. Since we focus here on the choice between vinyl and nitrile, we have not investigated latex glove prices further.

<sup>115</sup> Catherine Galligan, Sustainable Hospitals Project, University of Massachusetts Lowell, personal communication.

<sup>116</sup> Centers for Medicare and Medicaid Services, "Table 1: Selected Community Hospital Statistics, 1999-2002," data drawn from *National Hospital Indicators Survey*, available at <http://cms.hhs.gov/statistics/health-indicators/t1.asp> (viewed October, 2003).

<sup>117</sup> This section draws heavily on "Vinyl Siding: More Uniform Plastic," *Consumer Reports* (August, 2003), pp.23-25; it is the source for this description of siding alternatives, except as noted.

<sup>118</sup> Electrospec Home Inspection Services, "Painting aluminum and vinyl sidings," available at <http://www.allaroundthehouse.com/lib.pqr.p3.htm> (viewed October 1, 2003).

<sup>119</sup> Stark and Stark law firm, "What is EIFS?" available at [www.njeifs.com/whatiseifs.html](http://www.njeifs.com/whatiseifs.html) (viewed October 8, 2003).

<sup>120</sup> Stark and Stark law firm, "Can EIFS be repaired?" available at [www.njeifs.com/caneifsberepaired.html](http://www.njeifs.com/caneifsberepaired.html) (viewed October 8, 2003).

<sup>121</sup> Bruce Hampton, Hickory Woods Consortium, personal communication.

<sup>122</sup> BobVilla.com, "Material and Construction Options for Windows," available at <http://www.bobvilla.com/ArticleLibrary/Subject/Windows/Residential/WindowMaterials.html> (viewed September 25, 2003).



<sup>123</sup> Comfort Line Inc., "The right choice...Fiberglass!"

<sup>124</sup> On the carcinogenicity of fibrous glass products, see US Department of Health and Human Services, Public Health Service, National Toxicology Program, "10th Report on Carcinogens, Tenth Edition" (December 2002), available at <http://ehp.niehs.nih.gov/roc/toc10.html#toc> (viewed November 2003). For an overview of occupational hazards, see American Lung Association of Georgia, "Facts About Fiberglass," available at <http://abrannen.home.mindspring.com/alag/fbrglass.htm> (viewed September, 2003). For a history of science and policy on fiberglass, see Peter Montague, "A Carcinogen that is Everywhere," *Rachel's Environment and Health News* #444 (June 1, 1995), available at [http://www.rachel.org/bulletin/index.cfm?issue\\_ID=681](http://www.rachel.org/bulletin/index.cfm?issue_ID=681) (viewed November 2003).

<sup>125</sup> Cramer, Oneida, "Window Restoration," available at <http://www.homeissues.com/viewarticle.cgi?article=152&category=3> (viewed September 26, 2003).

<sup>126</sup> BobVilla.com.

<sup>127</sup> Comfort Line Inc. "The right choice...Fiberglass!"

<sup>128</sup> See Cramer, Oneida; John Paquette, "What's Wrong with Vinyl Windows?" East Row Historic District, Newport, KY, available at <http://eastrow.org/articles/vinylwindows.html> (viewed October 2, 2003).

<sup>129</sup> Ross, Mickey, President Ross Window Corp, "New Windows Give a 'Green' Outlook," New York Association of Realty Managers, available at <http://www.nyarm.com/oct00/windows.html> (viewed September 26, 2003).

<sup>130</sup> Comfort Line Inc. "The right choice...Fiberglass!"

<sup>131</sup> Prices from 5 Points Sash and Doors employee, personal communication (September 26, 2003).

<sup>132</sup> The total employment in NAICS industry 3261, "plastics product manufacturing," was 826,615. Of these workers, 526,382, well over half, were described only as being in industry 326199, "all other plastics product manufacturing." See [http://www.census.gov/epcd/ec97/us/US000\\_31.HTM#N326](http://www.census.gov/epcd/ec97/us/US000_31.HTM#N326).

<sup>133</sup> SPI, *Size and Impact of the U.S. Plastics Industry*, as described on <http://www.plasticsdatasource.org/impact.htm>. <http://www.chlorallies.org/employ.html> (viewed October 7, 2003). The data refer to a recent but unspecified year.

<sup>135</sup> SRI Consulting (Menlo Park, CA), *Chemical Economics Handbook: Vinyl Chloride Monomer* (December, 2000), and *CEH Marketing Research Report: Polyvinyl Chloride (PVC) Resins* (September, 2003).

<sup>136</sup> It seems likely that the employment data in Table 17 err more often in the direction of including too many workers, such as those who make other products at the same plants. The one obvious case of incompleteness in the other direction, underestimating employment, seems smaller by comparison. If too many workers are counted in Table 17, then the true average productivity—pounds of PVC per worker—is higher than our estimated 2.82 million pounds per worker, and the number of workers needed to produce the entire industry output is lower than 5,600. Further support for the guess that the industry has higher productivity, and hence lower total employment, than our estimates can be found in Environment Canada's study of chlorine-related industries in Canada in 1993. That study describes three PVC resin plants, with an average capacity of 3.14 million pounds per worker. If there have been advances in productivity since 1993, the capacity per worker should now be even higher. See Environment Canada, "A Technical and Socio-Economic Comparison of Options to Products Derived from the Chlor-Alkali Industry" (1997), Chapter 9.

<sup>137</sup> The 200 workers were also producing a larger quantity of EDC, a VCM precursor; some of the EDC was exported, and some was used to produce VCM. Thus the workers' actual productivity was higher (and estimated US labor requirements per million pounds of VCM should be lower) than the numbers presented in the text.

<sup>138</sup> PVC Container Company, Eatontown, NJ, interview with sales representative (October 28, 2003).

<sup>139</sup> Omni International (Bedford, NH), High Five, and Kimberly Clark company representatives, personal communications (October, 2003).

<sup>140</sup> Information on Westlake is drawn from Westlake's website, at <http://www.westlakegroup.com/index2.html> (viewed November, 2003).

<sup>141</sup> CertainTeed website, <http://www.certainteed.com> (viewed November, 2003).

<sup>142</sup> Calculated from the Bureau of Labor Statistics, Job Openings and Labor Turnover Survey, Tables 4 and 6, available at <http://www.bls.gov/jlt/> (viewed October 8, 2003).

<sup>143</sup> See the discussion of the Just Transition program in Frank Ackerman and Rachel Massey, "Prospering With Precaution" (2002), available at [http://www.ase.tufts.edu/gdae/policy\\_research/PrecautionAHTAug02.pdf](http://www.ase.tufts.edu/gdae/policy_research/PrecautionAHTAug02.pdf). On the Just Transition program, see James P. Barrett and J. Andrew Hoerner, "Clean Energy and Jobs: A Comprehensive Approach to Climate Change and Energy Policy" (Washington, DC: Economic Policy Institute, 2002).

<sup>144</sup> Most of the information presented in this section is drawn from Greenpeace International, "PVC-Free Future: A Review of Restrictions and PVC free Policies Worldwide, 8th Edition" (2001) and Washington Toxics Coalition, "Anti-Vinyl, -PBT and -Dioxin Resolutions Adopted Across America and Around the World" (2002).

<sup>145</sup> See <http://www.cleanmed.org>.

<sup>146</sup> Unless otherwise noted, all information in this section is from Greenpeace (2001).

<sup>147</sup> Health Care Without Harm, "Glanzing Clinic in Vienna is First PVC-Free Pediatric Unit Worldwide," Press release (June 13, 2003).

<sup>148</sup> "Four Top Hospital Group Purchasers to Cut Mercury, PVC," *Waste News* (November 5, 2002).

<sup>149</sup> Saint-Gobain Performance Plastics, "TYGON® Medical Plasticizer-Free Tubing Developed Specifically for DEHP-Plasticizer and PVC Replacement in Medical Applications" (no date).

<sup>150</sup> See <http://www.nike.com/nikebiz/nikebiz.jhtml?page=27&cat=sustainable> (viewed November, 2003). Follow the "PVC-free" link and click "close" in the first panel to see details on current PVC-free shoe brands.

<sup>151</sup> "Athletic shoe makers had better leave stockings and not shoes out for Santa this Christmas, suggests Greenpeace," *Pesticide & Toxic Chemical News* 30 no. 8 (Dec 17, 2001), p.28.

<sup>152</sup> Sony Corporation, "Sony and the Global Environment," available at [http://www.sony.net/SonyInfo/Environment/environment/communication/report/2003/pdf/e\\_2003\\_05.pdf](http://www.sony.net/SonyInfo/Environment/environment/communication/report/2003/pdf/e_2003_05.pdf) (viewed November, 2003).

<sup>153</sup> See promotional materials at <http://www.sony.net/SonyInfo/Environment/environment/communication/advertisement/08> (viewed November, 2003).

<sup>154</sup> US Grains Council, "Global Update" (March 14, 2003), available at [http://www.grains.org/news/global\\_updates/glo-03-14-03.pdf](http://www.grains.org/news/global_updates/glo-03-14-03.pdf) (viewed November, 2003). It is worth noting that PLA is currently manufactured by Cargill from genetically engineered corn, which itself poses environmental hazards. Plant-based polymers can be produced sustainably in principle and do not require genetic engineering for their production.

<sup>155</sup> See company information at <http://www.toshiba.co.jp/env/english/04/index3.htm> (viewed November, 2003).

<sup>156</sup> IKEA Press Room, "IKEA CEO speaks at a Greenpeace conference in London," (October 10, 2001), available at [http://www.ikea.com/about\\_ikea/press\\_room/press\\_release\\_int.asp?pr\\_id=492](http://www.ikea.com/about_ikea/press_room/press_release_int.asp?pr_id=492) (viewed November, 2003).

<sup>157</sup> See <http://www2.marksandspencer.com/thecompany/mediacentre/corporatesocialresponsibility/2001.shtml> (viewed November, 2003).

<sup>158</sup> For case studies on green buildings, see <http://www.usgbc.org/Resources/links.asp#4> (viewed November, 2003).

<sup>159</sup> Healthy Building Network, "Green Healthcare Construction Case Studies," available at [http://www.healthybuilding.net/healthcare/Green\\_Healthcare\\_Case\\_Studies.pdf](http://www.healthybuilding.net/healthcare/Green_Healthcare_Case_Studies.pdf) (viewed November, 2003).

<sup>160</sup> Brett Goldstein, ed., *Green and Lean: Designing and Building an Affordable, Resource-Efficient Home* (Washington, DC: Green Home, 2000).

<sup>161</sup> Information on Erie Ellington Homes is available at Hickory Consortium, "Erie Ellington, Dorchester, Massachusetts," available at [http://www.hickoryconsortium.org/erie\\_ellington.htm](http://www.hickoryconsortium.org/erie_ellington.htm) (viewed July, 2002). Additional information was provided by Bruce Hampton, Architect, Hickory Consortium, personal communication (November, 2003).

<sup>162</sup> Goldstein (2000) p.29.

<sup>163</sup> *Ibid.*

<sup>164</sup> Information on the Rittenhouse Sheraton is from Barry Dimson, co-owner, personal communication (September, 2002); also see [www.sheraton.com/philadelphiarittenhouse](http://www.sheraton.com/philadelphiarittenhouse).

<sup>165</sup> Barry H. Dimson, "The Economics of Green Hotels," (January 23, 2002).

<sup>166</sup> See the Adat Shalom website at <http://adatshalom.net>, which is the source for this account.

<sup>167</sup> See <http://www.myhouseisyourhouse.org/> for information on Building in Good Faith.



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Update on the Environmental Health Impacts of  
Polyvinyl Chloride (PVC) as a Building Material:  
Evidence from 2000-2004

a commentary for the U.S. Green Building Council

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## OVERVIEW

In December 2000, the Healthy Building Network and the Center for Maximum Potential Building Materials submitted to the U.S. Green Building Council (USGBC) a briefing paper that summarized the environmental health effects of polyvinyl chloride (PVC) building materials[1]. Since that time, the USGBC's deliberations over PVC have continued and evolved. This report, therefore, represents an update of the scientific evidence. It is intended to serve as a reader's guide to some of the most important documents, reports, and data submitted on behalf of the Healthy Building Network to the Technical and Scientific Advisory Committee (TSAC) in response to its November 2003 solicitation for further evidence.

An impressive amount of research has been generated on the health effects of PVC since 2000. Taken as a whole, these studies substantially reinforce and extend the concerns that were raised at that time. This report covers a fraction of the many dozens of reports that the Healthy Building Network is submitting to the TSAC for its consideration. A complete annotated listing of those reports is available on the Healthy Building Network website (<http://www.healthybuilding.net>).

Highlighted in the discussion that follows are--

- 1) reports linking the creation of chlorine gas to significant releases of mercury by chlor-alkali facilities;
- 2) reports demonstrating multiple cancer threats to PVC workers, including a newly documented link between PVC dust and lung cancer;

- 3) data documenting the constant contamination of communities located near PVC facilities with vinyl chloride, a known carcinogen;
- 4) reports on the endocrine-disrupting properties of PVC plasticizers, including evidence for DNA damage in human sperm at background levels;
- 5) reports linking gaseous emissions from vinyl materials in home and offices to respiratory symptoms in workers and asthmatic symptoms in children;
- 6) reports documenting the inability of all known methods of disposal (incineration, landfilling, recycling) to safely and inexpensively manage PVC waste.

TSAC's solicitation for evidence comes at a critical time in the public awareness of PVC. Three years ago, knowledge about the environmental health problems associated with vinyl was held mainly by environmental researchers, members of the medical community, and firefighters. Now, the hazards of PVC are widely understood by the members of the concerned public—sometimes for very chilling reasons. The incineration and collapse of the World Trade Center in 2001, for example, sent a dioxin-filled plume over lower Manhattan. The hazards of burning vinyl were subsequently discussed on FOX News[2], and Senator Jon Corzine introduced the Chemical Security Bill, which identified the untracked production and transport of toxic chemicals—including the industrial feedstocks for PVC—as threats to homeland security[3]. The release of the documentary film “Blue Vinyl” likewise brought the cancer deaths of PVC workers into the public eye and inspired many green building projects. One is the faith-based initiative Building in Good Faith, which has vowed to eliminate PVC from construction projects involving places of worship[4].

Two different international accords, the European Union's REACH proposal and the United Nation's Stockholm Convention, have shined a global spotlight on PVC. REACH is a harmonized policy on chemicals that is still being deliberated by the European Parliament and Commission. It would require the registration of all toxic chemicals, including the class-A carcinogen vinyl chloride, and any hormone-disrupting additives[5]. The Stockholm Convention, which goes into effect in 2005, aims to reduce and eliminate releases of persistent organic pollutants (POPs) to air, water, land, and product. For unintentionally produced POPs, such as PVC-generated dioxin, the Convention requires that "consideration should be given to alternatives." More specifically, each signatory country shall "promote the development and, where it deems appropriate, require the use of substitute or modified materials, products and processes to prevent the formation and release of the chemicals"[6].

Not surprisingly, then, many downstream companies and investors are also beginning to distance themselves from PVC. Sony, Ricoh, Hewlett-Packard, Nikon, Seiko Instruments, General Motors, and Honda have all recently pledged to eliminate completely or significantly reduce PVC in their products; Honda intends to create a recyclable, PVC-free car by 2010[7].

Socially responsible investment firms, too, have issued warnings about PVC. Here, for example, is the description of PVC provided to clients by Domini investment group:

*PVCs are environmentally hazardous throughout their lifecycle (production, use, and disposal). Dioxin, a known human carcinogen, is created during the production of PVC feedstocks, as well as when PVCs are burned in waste incinerators. Among other things, dioxin has been linked to endocrine disruption, reproductive abnormalities, neurological problems, and infertility in humans and animals. In addition, large amounts of chemicals called "phthalates" are used to*

*manufacture PVC products. A commonly used phthalate plasticizer called diethylhexyl-phthalate (DEHP) is a probably reproductive toxicant, as well as a toxicant of the liver and kidney....*

*PVCs are...extensively used in building materials such as furniture and floor coverings. We will **support** resolutions asking companies to report on the risks, financial costs, and benefits, and environmental and health impacts of the continued use of PVCs in these types of products[8].*

## I. UPDATE ON DANGERS ASSOCIATED WITH PRODUCTION

### A. The Mercury Connection

The first step in the PVC production process is the generation of elemental chlorine. This gas is created in chlor-alkali facilities by running an electrical current through salty brine in the presence of a catalyst. The result is caustic soda (sodium hydroxide) and chlorine. Nine chlor-alkali facilities in the United States still use mercury as their catalyst, a 50-year-old technology. Mercury-cell chlor-alkali facilities produce only ten percent of the nation's chlorine but, in so doing, contribute hugely to annual atmospheric emissions of mercury. All together, 3,000 tons of mercury are currently in use by these plants.[9].

In the last few months, mercury-cell chlor-alkali plants have made headline news because of the disconnect between the amount these plants report to the Toxics Release Inventory (TRI) as their annual mercury releases and transfers (15 tons) and the amount consumed in manufacturing (30 tons). This is a difference of 15 tons of mercury. There exists an even greater disparity between the TRI figure and amount of new mercury purchased by these plants (130 tons in 2002) This is a difference of 115 tons[10]. What happened to all this mercury? This question has been taken up by state and federal regulators as well as environmental watchdog organizations. In December 2003, the



National Resources Defense Council along with the Sierra Club sued the EPA for changes in regulations that they contend fail to address the question of where all the missing mercury is. The EPA itself admitted in the Federal Register that the fate of mercury consumed in these facilities “remains somewhat of an enigma”[11]. If, in fact, the missing mercury is being seeded into the air as fugitive emissions, as many suspect, then the contribution of chlorine manufacturing to the mercury loading of the atmosphere far exceeds that of the coal-burning power plants, which, heretofore, have been presumed to be the number one source of atmospheric mercury. (All together, coal-burning power plants in the United States release 50 tons of mercury into the air each year.)

In 2000, the Vinyl Institute asserted that 20 percent of the chlorine produced in the United States by the mercury process is used to produce vinyl[12]. If so, then the production of PVC is directly responsible for the annual of release into the atmosphere of at least six tons, and as much as 26 tons, of mercury.

What makes the PVC-mercury link even more significant is the emerging evidence for neurological damage among children at very low levels of mercury exposure.

When elemental mercury from chlorine manufacturing plants is released to the atmosphere as a vapor, it can be carried long distances before returning back to earth. Once it does, methylating bacteria quickly convert the metal into an organic form, methylmercury, which is a powerful brain poison as well as a bioaccumulating, persistent pollutant. From here, it is quickly siphoned up the food chain, reaching its highest levels in fish and seafood. The EPA now estimates that 630,000 infants are born *each year* in

the United States at risk for neurological damage from exposures to methylmercury (that is, infants who receive *in utero* doses of methylmercury equal to or greater than the EPA's established reference dose for safety)[13]. In other words, one in every six U.S. babies now comes into the world with prenatal mercury exposures known to be associated with an increased risk for developmental harm to the brain. The adverse effects of prenatal mercury exposure include deficits in memory, attention span, motor control, and the ability to learn.

Other recent studies on methylmercury reveal evidence for widespread exposure as well as serious health effects at background dosages. The Centers for Disease Control estimates that 8 percent of U.S. women have body burdens of methylmercury that exceed the EPA's recommended reference dose[14]. A study of children on the Faroe Islands who were exposed to methylmercury from their mother's seafood consumption during pregnancy showed deficits in brain stem functioning that persisted into adolescence. The researchers concluded that "the neurotoxic effects from intrauterine methylmercury exposures are irreversible"[15]. A 2002 study published by a team of researchers from Johns Hopkins University found a link between mercury body burden and risk for heart attack. The researchers concluded that the ongoing contamination of fish with mercury "diminishes the cardioprotective effect of fish intake"[16].

These and other studies have prompted the Food and Drug Administration, as well as the Environmental Protection Agency, to issue more stringent advisories for fish consumption for women and children—including, as of 2004, restrictions on eating canned tuna. Even these new, stricter dietary advisories have been challenged by a leading health, consumer, and environmental groups as insufficiently protective[17].

The European Union's Food Safety Authority also warned, in February 2004, that mercury exposure from typical levels of fish consumption places women and children at risk[18]. In the same month, the European Commission released a report about the impact of chlor-alkali plants on mercury flow in Europe and the world[19].

#### B. Effects on Workers

Once chlorine is generated and combined with carbon to form ethylene dichloride (more on this intermediate product below), the next major step in the PVC manufacturing process is the synthesis of vinyl chloride monomer. The ability of vinyl chloride to cause angiosarcoma of the liver is well known. New studies demonstrate risks for other occupational cancers as well as non-cancer diseases.

A 2003 Italian study found among PVC workers significantly increased mortality from all causes of death, all tumors, lung cancer, lymphomas, leukemias, and liver cirrhosis[20]. This study is important because the authors used other blue-collar workers as the internal reference group. That is, rather than compare PVC workers to members of the general public, the authors compare probably exposed workers with unexposed workers, which is a less-biased method.

A 2003 study of workers in a PVC plant in Louisville, Kentucky found strong associations with angiosarcoma and vinyl chloride exposure. This study also uncovered a cluster of brain cancers that could not be associated with vinyl chloride exposure *per se* but which was generally associated with having worked in a PVC facility[21]. This

unexplained cluster remains of interest because the Italian study also found brain cancers among its PVC workers.

A 2003 study from Taiwan reports on an interaction between vinyl chloride exposure and Hepatitis B infection (HBV). Workers without a history of chemical exposure but who were infected with HBV had a four-fold increase in angiosarcoma. Workers free of the viral infection but with vinyl chloride exposure experienced a 26-fold increase in angiosarcoma. However, the highest risk was found among workers both exposed to the virus and to vinyl chloride: the risk of these workers for liver cancer was elevated by a factor of 396. (Smoking, alcohol consumption, and medical history were all accounted for.) This study shows that vinyl chloride is a more powerful liver carcinogen than hepatitis B, which is a well-known cause of liver cancer. This study also demonstrates a synergistic interaction between vinyl chloride and HBV that resembles that seen between tobacco smoke and asbestos exposure.[22]

The next step in PVC manufacture is the polymerization of vinyl chloride monomer. This process creates a fine powder, which is handled by workers known as PVC baggers. Recent studies have documented increased rates of lung cancer and other pulmonary diseases within this group of workers.

A 2003 Italian study of 1,668 PVC workers found that baggers were exposed to high levels of respirable PVC dust. These workers, who were not exposed to vinyl chloride monomer, suffered from an increased risk of lung cancer associated with exposure to this dust. Age and smoking were controlled for[23].

Possible mechanisms for the link between PVC dust exposure and lung cancer are suggested by two animal studies that investigated lung changes in rats exposed to PVC dust. Funded by the plastics industry itself, this set of studies, also published in 2003, found evidence for a PVC-induced acute inflammatory reaction in the lung as well as more persistent alterations in the pulmonary immune profile. These changes were evident whether chemical additives coating the PVC particles had been washed off or not. The authors conclude, "Our findings suggest that immunologic mechanisms are directly or indirectly involved in the pathogenesis of lung changes after exposure to PVC dusts"[24].

### C. Effects on Communities

The ability of vinyl chloride monomer to drift beyond the factory fence line remains a primary issue. However, the public health problems start even before vinyl chloride is manufactured. The material created as an intermediate between chlorine gas and vinyl monomer is called ethylene dichloride (EDC), a substance that is classified as a possible carcinogen and is notoriously capable of leaching into groundwater. In September 2003 in Botany, Australia, EDC was found during monitoring of deep groundwater near the chemicals firm Orica, which manufactured EDC for the PVC industry. Further testing revealed that three fingers of EDC are now moving towards Botany Bay[25].

In February, 2002, a PVC plant in Saugus, California was raided by multiple federal agencies under the direction of the FBI as part of an investigation of claims that the company had repeatedly released toxic chemicals and faked air emissions data as part

of an organized cover-up. Among other falsifications, the EPA discovered that the plant's air emissions had routinely exceeded quarterly limits, in spite of claims to the contrary. Ten months later, the company ceased its PVC resin-manufacturing operation[26].

In Plaquemine, Louisiana, a trailer park that is home to 300 residents was forced to close in 2003 when vinyl chloride was detected in their drinking water. Residents there report an excess of miscarriages. The poisoning of the Plaquemine aquifer launched a criminal investigation by state and federal authorities and a front page story in the *New York Times* [27].

During that same month, a newspaper investigation of air emissions from plants in Louisville, Kentucky revealed that residents were being exposed to toxic chemicals, including vinyl chloride, that greatly exceeded EPA's health-based limits [28]. Chemist Wilma Subra has studied company and public health records of air quality in the neighborhood of the Louisville plants, as well as around a range of PVC plants in Louisiana, and found consistent patterns of exposure to school children, seniors, and other area residents to vinyl chloride, dioxin, and other toxic chemicals exceeding regulated health standards[29].

Threats to communities surrounding PVC plants include those in eastern Europe. Testimony by Children of the Earth before the European Commission at a 2000 public hearing on PVC revealed a long history of grievous problems at one such plant in the Czech Republic. They ranged from crop deaths caused by chlorine gas releases to dioxin-contaminated ash from fires and explosions[30].

All together, the data from so-called “fence-line studies” indicate that release of toxic chemicals from PVC facilities and the threats that these releases pose to the surrounding communities are not the result of a few isolated accidents or a few bad actors within an otherwise well-regulated industry. Rather, they are result of routine operations of an inherently dangerous industrial process that is also, by its very nature, prone to frequent accidents and upsets. According to all available data, vinyl chloride monomer production results in a constant exposure of neighbors to VCM and/or EDC[31].

## II. UPDATE ON DANGERS ASSOCIATED WITH USE

The smell of PVC is apparent to anyone who has bought a new shower curtain and hung it in a bathtub. And a 2002 study has shown that a single vinyl shower curtain can, in fact, raise indoor air toxics concentrations for longer than a month[32].

In addition to the volatilization of organic chemicals in PVC products, threats to human health associated with the use of polyvinyl chloride building materials can originate from degradation of the vinyl material itself. There is also growing concern about the endocrine-disrupting potential of the phthalate plasticizers used to make PVC pliable.

### A. Threats Associated with Degradation

A 2003 Finnish study investigated a high incidence of adult-onset asthma among employees working in an office building. Rates of asthma in this workplace were nine times higher than that among Finnish workers similarly employed. Researchers

discovered that degraded vinyl floor covering had released volatile organic chemicals such as 3-ethyl-1-hexanol and 1-butanol, into indoor air as well as underlying concrete slabs. When the floor covering was removed, VOC levels in indoor air decreased as did the prevalence of workers' symptoms. Indeed, after the removal of vinyl flooring, several employees found they no longer needed asthma medication at all[33].

Other studies from around the world corroborate these findings. Damp PVC flooring and carpeting have been shown to degrade indoor air quality through release of volatile organic compounds[34]. A study of more than 10,000 Swedish children found that the combination of floor moisture and PVC flooring significantly increased asthmatic symptoms[35].

#### B. Threats Associated with Phthalate Emissions from PVC Building Materials

There are many kinds of phthalates. Some are used primarily in cosmetics and fragrances. Others are used for printing inks, pesticides, or pharmaceutical products. Di(2-ethylhexyl)phthalate (DEHP) is the main plasticizer for PVC. DEHP is an animal carcinogen, an endocrine disrupter, and a developmental toxicant, with the male reproductive system considered the system most sensitive to the effects of DEHP.

Research on health effects of phthalates has exploded during the last four years. This report references only those phthalates immediately relevant to PVC building materials. Such studies fall into one of three categories: studies documenting the release of phthalates into the environment from vinyl building materials; studies documenting human exposures; and studies documenting human health effects from such exposures.



### *1. Release of Phthalates into Indoor Air*

A 2004 study from Japan measured phthalate levels in samples of indoor air from 27 different houses in Tokyo. Levels were surprisingly high in all homes, reaching their highest levels in newly constructed buildings. The authors conclude, “This research indicated that exposure to phthalate esters through inhalation or air from the indoor environment is as important as dietary intake of phthalate esters, and can contribute to daily intake to a much greater extent than has been assumed hitherto”[36].

A 2004 study from Denmark measured phthalate emissions from different materials. The highest levels of phthalates were emitted from wax-covered polyolefine flooring. However, this phthalate was dibutylphthalate (DBP), which the National Toxicology Center identifies as a less toxic substance than DEHP. (DBP is “of minimal concern” for potential effects on human development and “of negligible concern” for effects on the adult reproductive system. By contrast, the National Toxicology Program has expressed “serious concern” about the possible harm of DEHP exposure to the reproductive tract of developing male fetuses. More on this below.) The polyolefine floor released no DEHP. By contrast, PVC materials did emit DEHP as well as DBP[37].

These results support those of a pilot study published in 2002 which identified vinyl flooring and vinyl wall décor as the source of DEHP in dust particles in a child’s room[38].

### *2. Human Exposure to Phthalates*

In 2003, the Centers for Disease Control released the results of its extensive body burden survey, which attempts to measure concentrations of common chemical

contaminants in a representative sample of the U.S. population. The CDC survey found nearly ubiquitous exposure to phthalates among all age, ethnic and gender categories. Levels of DEHP were highest in children[39]. This study corroborated a smaller CDC study, published in 2000, which also detected phthalate metabolites in the urine of nearly every individual in a U.S. reference population[40].

Two recent German studies also report on phthalate levels in human urine. The first study, published in 2003, uncovered strikingly high levels of DEHP in the urine of residents in the southern city of Erlangen. All subjects tested had some level of DEHP metabolite in their urine. More than ten percent had values greater than the “tolerable daily intake” limit (TDI) used by European Union, and nearly one-third of subjects exceeded the U.S. EPA’s reference dose (RfD). The authors concluded, “We are not aware of any other environmental contaminant for which the TDI and RfD are exceeded to such an extent within the general population”[41].

The second German study, carried out by the same team of researchers, was published in 2004. In this study, investigators compare levels of DEHP metabolites in the urine of nursery school children, their parents, and their teachers. They found that children’s exposures to DEHP were roughly double that of adults. “Routes of the ubiquitous exposure to DEHP remain indistinct[42].”

### *3. Human Health Effects from Phthalate Exposure*

A number of pre-2000 studies highlighted the connection between phthalate environments and asthma or other bronchial obstruction problems in children. Much of

the work on phthalates in the last four years has focused on understanding the connection between phthalates and developmental concerns.


A review published in 2003 by the environmental committee of the American Academy of Pediatrics looked at prenatal risks created by DEHP exposure during pregnancy and concluded there were not enough human studies to conclude that phthalates are safe[43].

In July 2000, the National Toxicology Program's Center for the Evaluation of Risks to Human Reproduction concluded its evaluation of seven phthalate esters at an expert panel meeting in Virginia. All phthalates were ranked as to their level of concern. All but DEHP received marks of "low, minimal, or negligible." DEHP was not only singled out as a substance of "serious concern" for the possibility of its adverse effects to the developing reproductive system of boy babies, but the panel also expressed concern current estimated adult exposures to DEHP might be sufficient to adversely affect male fetuses in pregnant women. They also expressed concern about apparently higher exposure levels in infants and children[44].

In the same year, a team of researchers in Puerto Rico documented a correlation between high DEHP levels in young girls and premature breast development. Puerto Rican girls with dramatically early breast development (with an average age of 31 months) had seven time more DEHP in their blood than a matched group of girls without early breast development. "This study suggests a possible association between plasticizers with known estrogenic and antiandrogenic activity and the cause of premature breast development in a human female population"[45].

Associations have also been found between DEHP exposure and DNA damage in the sperm of adult males. As part of a 2003 study in Boston, researchers collected urine and semen samples from 168 subfertile men with no known occupational exposure to DEHP reported. Increasing levels of DEHP metabolite in urine were associated with decreasing levels of genetic integrity in sperm cells. “In conclusion, this study represents the first human data to demonstrate that urinary MEP [a DEHP metabolite], at environmental levels, is associated with increased DNA damage in sperm[46].”

### III. UPDATE ON DANGERS ASSOCIATED WITH DISPOSAL

Recent studies on the disposal problems presented by PVC confirm an earlier established truth: there is no safe way to get rid of it, and no good way to recycle it. At the end of its life span, PVC dies one of four deaths: it is buried in a landfill; it is burned in an incinerator (and then its ashes are buried in a landfill); it is “downcycled;” or it burns up in a fire that is either set accidentally or, as in the case of arson or terrorism, on purpose. 

Perhaps the most telling commentary on PVC’s disposal woes is found on the website of the tiny Canadian town of East Gwinlimbury, whose official mascot is a beaver swimming in a lake. East Gwinlimbury boasts a very enthusiastic Environmental Services Advisory Committee. Among other tasks the committee runs an annual Non-Blue Box Plastics Collection Day to recover plastic trash that is otherwise not picked up at curbside. Gladly accepted are Styrofoam, packing materials, and ice cream tubs.

However, “we cannot accept PVC since these material (grey sewer pipe, Venetian blinds etc.) cannot be safely recycled.”

The difficulty of recycling PVC waste was taken up in a 2000 study for the European Commission. Recycling of PVC, according to this report, has technical limits, including the fact that recycled materials are not equivalent to virgin PVC. Moreover, many vinyl products contain lead and cadmium as stabilizers, and these heavy metals can become dispersed during the recycling process and contaminate the recyclates. Examining future trends in PVC disposal in Europe, the study concludes that the costs of recycling PVC will remain high, necessitating financial assistance. “As a consequence, the mechanical recycling [of PVC] must be subsidized, i.e. the additional costs compared to waste disposal must be borne by society, industry, or waste owners.” The authors estimate these costs at between 90-290 million Euro per year. In spite of these subsidies, however, “mechanical recycling is not qualified to contribute significantly to the management of PVC post-consumer wastes in the next decades, reaching at most 18 percent of total PVC waste arising. This means that the major part of future PVC waste volumes has to be recovered or disposed or in other ways...”[47].

One other way is landfilling. This is also an imperfect solution. Another 2000 report for the European Commission reports on the behavior of PVC in landfills. This study estimates that 28 percent of the total amount of lead in municipal waste landfills comes from PVC products; however, the migration of lead and other heavy metals out of landfilled PVC could not be quantified. The report describes phthalate emissions in landfill gases as well as leachate. It concludes—

“There is no evidence that the release of additives will come to a standstill. Thus, it is expected that this process will last for a very long time....The technical guarantee for landfill bottom liners and pipes for leachate collection is restricted to 80 years. Emissions resulting from the presence of PVC in landfills are likely to last longer than the guarantee of the technical barrier”[48].

Incineration is the other alternative. Another 2000 report for the European Commission examines this option. It notes that the high chlorine content of PVC places a high demand on the use of alkaline reagents in the air pollution control systems of incinerators. The additional costs of these reagents amount to 165 Euro per ton of rigid PVC. But since these costs are spread across all materials sent to the incinerator, the additional expense of burning PVC is currently paid by the incineration of other materials. “This effectively subsidizes PVC waste incineration.” The advantage of incineration, says this report, is that it destroys phthalates that would otherwise leach out of a landfill. On the other hand, incineration frees up lead and cadmium so that the ash that is subsequently buried from PVC incineration is more likely to contain mobile heavy metals than the original PVC matrix. The authors conclude—

“...it is likely that there will be benefits to be gained from diverting PVC away from incineration, particularly toward recycling, though there are clearly very finite limits to what can be recycled. There are also economic limits for separation of PVC mingled with other types of waste, Whatever the future for

PVC, this problem will remain with us for many years as a consequence of the large stock of long-lived PVC products currently in use...”[49].

Blazes other than those that occur inside the ovens of incinerators also destroy PVC building materials. Among the dangers when PVC burns in open fires are dioxin generation, the formation of hydrochloric acid mist, and the generation of thick, choking smoke. In September 2002, a wildfire in California’s Santa Clarita Valley claimed 25 acres of brush and dry creek bed full of PVC piping. The resulting black smoke closed roads and shut down train service[50]. A 1997 fire in a plastics plant in Hamilton, Ontario consumed 400 tons of PVC, triggered the evacuation of 700 residents, and generated so much hydrochloric acid that the metal on nearby fire trucks melted[51]. More than 200 firefighters who fought that blaze later filed claims that it destroyed their health[52]. In March 2004, one of these firefighters, Bob Shaw, died of cancer of the esophagus, and both his union as well as his personal physicians attributed his death to the 1997 PVC fire. (Nevertheless, Shaw’s claim for compensation was rejected by the Workplace Safety and Insurance Board, on the grounds that esophageal cancer has not been definitively linked to the occupation of firefighting.)[53]

The dioxin created by burning vinyl in the World Trade Center inferno was a topic taken up in a February 2004 report on the health and environmental consequences of that disaster.[54] The following month, the World Health Organization called for more protection for the developing brains of children against a variety of environmental toxicants, including dioxin. Its comprehensive study on the environmental threats to

children's health will be presented this June at a Budapest conference entitled "The Future for Our Children"[55].

#### SUMMARY

All together, data from the past four years indicates that PVC poses serious threats to environmental health at every stage of its existence. Its production contributes to the ongoing contamination of fish and seafood with methylmercury. Its manufacture and assembly is linked to lung cancer, as well as liver cancer, in workers. PVC plants routinely poison neighboring communities. The use of PVC as a building material contributes to the degradation of indoor air and is linked to respiratory symptoms in children and office workers. The plasticizers with which it is treated pose clear threats, at background level, to fetal development of the male reproductive tract and may also damage sperm cells in adult males. At the end of its life, PVC waste creates intractable disposal problems because it is expensive and unsafe to burn, it releases hazardous chemicals into groundwater and air when buried, and is not cheaply or easily recycled.



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# Dioxin, PVC, and Health Care Institutions

## What is dioxin?

Dioxin is the name given to a group of persistent, very toxic chemicals. The group includes chlorinated dibenzofurans, and dibenzo-dioxins, the most toxic of which is 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD). The group also includes related compounds which are structurally similar and are dioxin-like in their activity. The toxicity of these compounds is measured against TCDD using "toxic equivalents," which assign a fractional potency to each dioxin. Dioxins, defined here as dioxins and furans, have equivalence factors assigned to them. The US Environmental Protection Agency (EPA) has not assigned equivalence factors for brominated dioxins, brominated furans, brominated biphenyls and polychlorinated biphenyls (PCBs), although it is believed each group includes some dioxin-like compounds.

Dioxins and related compounds are highly persistent in the environment and in living organisms. They are bioaccumulative and fat-soluble. Their concentrations increase as they biomagnify up the food chain.

## What are the hazards of dioxin?

Dioxins are extremely toxic and potent environmental contaminants. They modulate and disrupt growth factors, hormones, enzymes, and developmental processes. In animals, dioxin causes cancer in multiple organ systems, sometimes at exposure levels as low as nanograms per kilogram of body weight. Prenatal exposure to dioxin in rodents substantially increases the risk of breast cancer later in life.<sup>1</sup> Human epidemiological studies conclude that dioxin causes cancer in humans as well.<sup>2</sup> A draft report by the EPA estimates that as many as one in 1,000 of the most highly exposed people in the general population are at risk of developing cancer because of dioxin.

Dioxin also has widespread effects on reproduction and development, as shown in animal and human studies. Tiny doses in the range of nanograms (one thousandth of one millionth of a gram) to micrograms (one millionth of a gram) per kilogram of body weight of dioxin can cause harm. Exposure to these levels on a single day during pregnancy cause permanent disruption of male sexual development in rodents, including delayed testicular descent, lower sperm counts, and feminized sexual behavior.<sup>3</sup> In primates, small dietary exposures to dioxin are associated with an increased risk and severity of endometriosis.<sup>4</sup> A study in humans also shows higher levels of dioxin in women with endometriosis than in a control population.<sup>5</sup>

Dioxin is particularly toxic to the developing immune system. Animal tests show that nanograms per kilogram doses given 1-4 times during pregnancy cause permanent alterations in the immune system of offspring.<sup>6</sup> Human studies also show an increased susceptibility to infection and changes in immune system parameters as a result of in utero exposure to ambient environmental levels of dioxin and dioxin-like compounds.<sup>7,8</sup> Low levels of exposure during pregnancy also alter thyroid hormone levels in mothers and offspring, perhaps explaining neurological effects, including learning disabilities, that are seen in carefully conducted primate studies.<sup>9</sup>

## How are we exposed?

The US EPA estimates that over 90% of our exposure is through food, with major sources including beef, dairy products, fish, pork, and breast milk. Dermal, oral and inhalation routes of exposures can also be important for people living near dioxin sources.

## What is the level of exposure in the general population?

The general population, through ordinary dietary exposures, carries a current body burden of dioxin that is near or above the levels that cause adverse effects in animal tests. Through food alone, Americans are getting 22 times the maximum daily dioxin exposure considered by the US EPA to be without adverse effects.

Breast milk contamination is such that the nursing infant, during vulnerable periods of development, is exposed to dietary levels of dioxin 35 to 65 times the amount considered safe. Nonetheless, breast feeding remains far superior to formula feeding for a variety of reasons, and reducing breast feeding is not an appropriate public health response.

## What are the sources of dioxins?

Dioxins are unintentionally formed during a variety of industrial processes that include chlorinated substances. Dioxin-like compounds can be generated and released to the environment from various combustion processes when chlorine donor compounds are present. Chlorine donor compounds can include polyvinyl chloride (PVC) plastic and other chlorinated compounds. Dioxin compounds can also be formed during the manufacture of chlorinated materials like PVC, chlorinated solvents and pesticides. Dioxins can also be formed during the bleaching of paper with chlorine, and in other industrial and combustion processes that include the presence of chlorine.

The primary source of dioxins from the health care sector has historically been waste incineration. Chlorine-containing products burned in incinerators, including medical devices and products, provide the chlorine necessary for dioxin formation.

New federal rules have resulted in the closing of most medical waste incinerators. In addition, large incinerators that will continue to operate must meet stricter emission limits. Those rules will eventually reduce the health care sector's contribution to dioxin levels in the environment. Although the contribution of dioxin from incinerators is declining, dioxin sources related to health care remain. The production of materials to create chlorinated health care products, like PVC IV bags and gloves, can result in dioxin formation. In addition, chlorinated health care waste that is burned in backyard burn barrels, or catches fire once taken to the landfill, has the potential to create and disperse dioxin. Once dioxin is emitted into the air from incinerators and other sources, rain, snow and dust can carry it to the surface of the earth, where it can enter the food chain.

## What is the evidence that the manufacture of PVC feedstocks is linked to dioxin formation?

The draft dioxin reassessment recently released by the EPA reviews the contribution of PVC manufacturing to dioxin emissions.<sup>10</sup> According to calculations of the Vinyl Institute (an industry trade association), reviewed and given a medium confidence rating by the EPA,<sup>11</sup> the production of PVC and its feedstocks result in air releases of 11.2-31.0 grams toxic equivalency (TEQ)<sup>12</sup> dioxins and furans per year. These levels may understate the contribution of dioxin from the manufacture of PVC throughout its life cycle, both because there may be dioxin releases to land and water during the production phase, and because dioxin may be formed during disposal of the end product.

## Under what conditions can the combustion of PVC result in dioxin formation?

The draft EPA dioxin reassessment also reviews the contribution of waste incineration to dioxin emissions. The report summarizes a large body of literature that finds carbon and catalysts must be present in an incinerator in order for dioxins to form.<sup>13</sup> PVC is usually the largest chlorine source in municipal and medical waste incinerators. The relationship between chlorine inputs into an incinerator and dioxin formation, however, depends upon combustion conditions.

For uncontrolled combustion, such as open burning of household waste, landfill fires, or building fires, a direct association between chlorine content of the combusted material and dioxin formation has been established. For example, a study of the open burning of household waste showed that waste containing larger amounts of PVC (4.5% vs. 0.2%) produced substantially larger amounts of dioxins in air emissions (269 vs. 44.3 microgram/kg waste burned) and ash (7,356 vs. 489 microgram/kg waste burned).<sup>14</sup>

In modern, commercial waste incinerators, the rate at which dioxins are formed and released depends upon chlorine inputs, incinerator design, operating conditions, the presence of catalysts, and pollution control equipment. While the EPA concludes, based on studies of modern waste incinerators, that the largest determinants of dioxin formation are operating conditions (including overall combustion efficiency, post-combustion flue gas temperatures, and residence times — and the presence of iron or copper catalysts) rather than chlorine content alone, there is little doubt that chlorine content of the waste feed is critical.

Several laboratory and incinerator pilot studies have found a direct relationship between chlorine loading and dioxin emissions.<sup>15</sup> In addition, the EPA's conclusion appears to rest largely on an analysis of incinerator emissions data by Rigo, et al. (1995), which has serious methodological flaws.<sup>16</sup> It is also important to note that the EPA conclusion refers only to stack gas emissions, which are a relatively small fraction of total dioxins released from incinerators, and does not consider releases in fly ash, bottom ash, and water discharges.

For any given waste incinerator, according to the EPA, conditions may exist in which changes in chlorine content of waste feed will correlate highly with dioxin and furan emissions. These conditions may prevail during start-up or shut-down, changes in waste feed rate, or operational upsets. Although modern commercial waste incinerators are designed and intended to be operated to minimize release of dioxins and other hazardous air pollutants, they are, nevertheless, an important source of dioxin releases.

### What is Health Care Without Harm's position on dioxin, PVC, and medical waste incineration?

Available data reveal a complex relationship among chlorine feed, design and operating conditions, and dioxin emissions. It is certain that chlorine sources are necessary for dioxin emissions, and PVC products are a large chlorine source. It is also certain that combustion, even in well controlled incinerators, will release dioxins in stack gases, fly ash, bottom ash, and water discharges. Moreover, even modern, well-designed incinerators do not consistently operate at optimal combustion conditions. Further, not all burning of chlorinated products occurs in controlled conditions, and uncontrolled burning can result in large dioxin releases.

For these reasons, along with concern about other hazardous pollutants emitted from waste incinerators — including mercury, particulates, sulfur and nitrous oxides, and hydrochloric acid — Health Care Without Harm has taken the pollution prevention position that PVC use should be minimized and ultimately eliminated, alternatives should be used when available without compromising patient safety or care, and all unnecessary waste incineration should be avoided.

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10. See US EPA, Report #: EPA/600/P-00/001Ab, March 2000.
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16. In 1995, the Vinyl Institute commissioned a report, prepared for the American Society of Mechanical Engineers, that purported to examine the relationship between PVC in incinerator waste feed and dioxin emissions (Rigo HG, Chandler JA, Lanier WS, *The relationship between chlorine in waste streams and dioxin emissions from combustors*, The American Society of Mechanical Engineers, 1995). After examining data from dozens of burns in a number of municipal and medical waste incinerators, the report concludes that there is no statistically significant relationship between fuel chlorine content and dioxin emissions. The analysis, however, is flawed in a number of significant ways. First, there was no attempt to control for differences in incinerator design or operating conditions so that the question of interest could be addressed independent of other variables. Second, the authors used data collected for regulatory compliance purposes and not intended to examine the relationship between chlorine input and dioxin output. Without actually knowing the PVC content of the waste feed, they were forced to use hydrochloric acid emissions as a surrogate for chlorine loading. Hydrochloric acid emissions can be used to approximate chlorine loading but do not provide precise estimates. Moreover, in the tested incinerators, dioxin concentrations were sampled at various points in the exhaust stream – from boiler outlet to further downstream – predictably a source of variability, since dioxin can be formed at various points in the exhaust, depending on temperature and fly ash composition. This sampling strategy provides a poor estimate of total dioxin emissions to the air and ash. In summary, this analysis relies on data that are poorly suited to answer the question of interest. A more complete referenced discussion of the connection between PVC incineration and dioxin formation may be found in: Thornton J., *Pandora's Poison: Chlorine, Health, and a New Environmental Strategy* (Chapter 7), MIT Press: Cambridge MA, 2000.



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# PVC & HEALTHCARE

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## INTRODUCTION

Polyvinyl chloride (PVC) is a chlorinated plastic polymer adapted for many different uses by the addition of fillers, stabilizers, lubricants, plasticizers, pigments, and flame retardants, depending on the intended application. The use of plasticizers (mainly phthalates) and stabilizers in rather high quantities constitutes a specific characteristic of PVC manufacturing compared to other types of plastic.<sup>1</sup> Lead and cadmium are widely used as PVC stabilizers for many applications, including construction and electric wire coating materials.

PVC is the most widely used plastic in medical products. It accounted for 27% of all plastic used in durable and disposable medical products in the U.S. in 1996. Approximately 445 million pounds of PVC were consumed in the manufacture of intravenous (IV) and blood bags, tubing, examination gloves, medical trays, catheters, and testing and diagnostic equipment in 1996.<sup>2</sup> Tubing, IV and blood bags, and gloves are the primary end-uses for PVC in disposable medical products. Other PVC products used in hospitals, which are not specific to healthcare, include office supplies and construction and furniture products (see Appendix 1 for a detailed list of products).

This white paper examines the life cycle hazards posed by PVC, with an emphasis on di-2-ethylhexyl phthalate (DEHP) exposures to patients and dioxin emissions from medical waste incinerators, and identifies methods and opportunities for reducing PVC use in hospitals.

## PROBLEM STATEMENT

Concerns about the use of PVC in medical care fall into two categories: 1) potential impacts on patient health and safety from the use of PVC containing DEHP and 2) public health and environmental impacts from PVC production, use, and disposal.

### *Patient Health and Safety*

PVC is a rigid plastic. To manufacture flexible PVC medical products, manufacturers add the plasticizer, DEHP.<sup>3</sup> Some flexible PVC medical products contain more than 50% DEHP. DEHP does not chemically bind to the polymer (polyvinyl chloride). Instead, it lies in the polymeric matrix and leaches out under certain conditions, causing direct patient exposures. Because DEHP preferentially dissolves in fat rather than water, blood and feeding formulas contain higher concentrations of DEHP than other fluids, such as saline and amino acid solutions. The largest patient exposures occur during dialysis, extracorporeal membrane oxygenation, exchange transfusions, or repeated blood transfusions in newborns and preterm babies.<sup>4</sup> Total parenteral nutrition (TPN) delivered through PVC tubing may also be a source of very significant exposure to DEHP.<sup>5</sup>

Though data from humans are sparse, the toxicity of DEHP has been extensively studied in various animal species. DEHP or its metabolites may cause toxic effects in various organ systems, depending on amount, route, and timing of exposures. Of particular concern, at exposure levels resulting from medical treatment with DEHP-containing medical devices, is toxicity to the developing male reproductive tract. Recently, the Expert Panel on Phthalate Esters from the National Toxicology Program's Center for the Evaluation of

Risks to Human Reproduction investigated the reproductive and developmental toxicity of DEHP and other related compounds.<sup>6</sup> In their summary statement, the expert panel expressed “serious concern” for the possibility of adverse effects on the developing reproductive tract of male infants exposed to high levels of DEHP from medical procedures such as those used in neonatal intensive care units (NICUs). They also expressed “concern” that the exposure of pregnant and lactating women to ambient levels of DEHP, largely from dietary sources, might adversely affect their offspring. When DEHP exposures from the use of PVC medical devices are added to general dietary exposures during pregnancy, the risk of adverse effects obviously increases. The Panel also expressed “concern” that, if infants and toddlers are exposed to levels of DEHP substantially higher than adults, adverse effects might occur in the developing male reproductive tract.

Additional concerns have been raised about the potential role of DEHP exposure in liver failure frequently encountered by neonates receiving TPN as well as its potential contribution to the development of bronchopulmonary dysplasia in infants ventilated through PVC endotracheal tubes.<sup>7,8</sup> These concerns deserve further investigation and remain unresolved.

Surprisingly, total DEHP exposure from concurrent use of multiple DEHP-containing medical devices has not been quantified. A Health Care Without Harm-sponsored study of PVC use in neonatal intensive care units found approximately 30 devices made of DEHP-containing PVC that are potential sources of DEHP exposure.<sup>9</sup> Routine use of these devices will expose developing male infants to levels of DEHP and/or metabolites at or above levels known to cause testicular toxicity in studies in relevant animal species.

### ***Public Health and Environmental Impacts of PVC Production and Disposal***

#### **PVC, DIOXIN, AND HEALTH CARE INSTITUTIONS**

The public health and environmental impacts of PVC production and disposal result from: 1) release of dioxins and furans generated as by-products during the production of PVC feedstocks; 2) dispersion of plasticizers and metal stabilizers, including lead and cadmium, during use and after disposal; and 3) formation of hydrochloric acid and novel toxic compounds, including dioxins and furans when PVC is burned. PVC

recycling opportunities are limited, and when “recycled” PVC is actually down-cycled into products usually made from other materials, delaying, but not ultimately mitigating, disposal hazards. Efforts to recycle other types of plastics may be ruined by contamination with even small amounts of PVC, making strict segregation of PVC from the plastics waste stream essential, though this is often difficult to achieve in practice.

Chlorinated dibenzo-dioxins and furans are extremely potent, persistent, and bioaccumulative environmental toxicants that contaminate the general food supply. They are unintentionally formed during a variety of industrial processes, including the manufacture of PVC feedstocks and incineration of PVC. They cause their toxic effects at picogram to nanogram per kilogram (kg) body weight levels of exposure and are detectable at levels of concern in the general population and wildlife of most industrialized nations. Inuits and other northern peoples are also significantly exposed through their diet of marine fish and mammals, revealing the capacity of these compounds to travel far from their source.

The draft dioxin reassessment recently released by the US Environmental Protection Agency (EPA) reviews the contribution of PVC manufacturing and waste incineration to dioxin and furan emissions.<sup>10</sup> According to calculations of the Vinyl Institute, reviewed and given a medium confidence rating by the EPA,<sup>11</sup> the production of PVC and its feedstocks result in air releases of 11.2–31.0 grams toxic equivalency (TEQ)<sup>12</sup> dioxins and furans per year. The EPA identifies municipal and medical waste incinerators as the leading sources of dioxin and furan emissions to air in the US: 1,250 and 488 grams TEQ annually, respectively.

Chlorine, carbon, and catalysts must be present in an incinerator in order for dioxins and furans to form.<sup>13</sup> PVC is usually the largest chlorine source in municipal and medical waste incinerators. The relationship between chlorine inputs into an incinerator and dioxin and furan formation, however, depends upon combustion conditions.

For uncontrolled combustion, such as open burning of household waste, landfill fires, or building fires, a direct association between chlorine content of the combusted material and dioxin and furan formation has been established. For example, a study of the open burning of household waste showed that waste containing larger amounts of PVC (4.5% vs. 0.2%) produced substantially

larger amounts of dioxins and furans in air emissions (269 vs. 44.3 microgram/kg waste burned) and ash (7,356 vs. 489 microgram/kg waste burned).<sup>14</sup>

In modern, commercial waste incinerators, the rate at which dioxins and furans are formed and released depends upon chlorine inputs, incinerator design, operating conditions, the presence of catalysts, and pollution control equipment. In its draft dioxin reassessment the EPA concludes, based on studies of modern waste incinerators, that chlorine levels in feed are not the dominant controlling factor for rates of dioxin and furan stack emissions. Instead, according to EPA, the largest determinants are operating conditions — overall combustion efficiency, post-combustion flue gas temperatures, and residence times — and the presence of iron or copper catalysts that support dioxin synthesis.

However, for any given waste incinerator, according to the EPA, conditions may exist in which changes in chlorine content of waste feed will correlate highly with dioxin and furan emissions. These conditions may prevail during start-up or shut-down, changes in waste feed rate, or operational upsets. Although modern commercial waste incinerators are designed and intended to be operated to minimize release of dioxins, furans, and other hazardous air pollutants, they are, nevertheless, a significant source of dioxin and furan releases. For example, the EPA estimates that municipal waste and medical waste incinerators contribute 44 percent and 18 percent, respectively, of dioxin and furan releases to air from quantified sources.

Although the EPA concludes that incinerator operating conditions are the dominant controlling factor for dioxin/furan emissions, there is little doubt that chlorine content of the waste feed also plays a major role. Several laboratory and incinerator pilot studies have found a direct relationship between chlorine loading and dioxin and furan emissions.<sup>15</sup> In addition, the EPA's conclusion appears to rest largely on an analysis of incinerator emissions data by Rigo, et al. (1995), which has serious methodological flaws.<sup>16</sup> It is also important to note that the EPA conclusion refers only to stack gas emissions, which are a relatively small fraction of total dioxins and furans released from incinerators, and does not consider releases in fly ash, bottom ash, and water discharges.

When addressing dioxin and furan formation and emissions, prevention, rather than control, should be

the highest priority. As the US Congress stated in the Pollution Prevention Act of 1990, "pollution should be prevented or reduced at the source wherever feasible" and "disposal or other release into the environment should be employed only as a last resort and should be conducted in an environmentally safe manner."

Moreover, the US is among over 150 nations that recently concluded negotiating an international treaty intended to virtually eliminate production, use, and formation of Persistent Organic Pollutants (POPs), two of which are dioxins and furans.<sup>17</sup>

The primary source of dioxins and furans from the healthcare sector is waste incineration. Chlorine-containing products burned in incinerators provide the chlorine necessary for dioxin and furan formation. Methods for preventing healthcare-related dioxin and furan releases include:

- 1) ceasing all non-essential incineration as a means for chemically and physically transforming waste;
- 2) eliminating large sources of chlorine from incinerator waste feed by a) phasing out the use of PVC, and/or b) separating chlorine-containing products from the incinerator wastestream and sending it directly to a landfill; and
- 3) optimizing incinerator operating conditions for that portion of the waste stream that must be incinerated. Inasmuch as this is an end-of-the-pipe solution, however, it should be considered only as a last resort.

In summary, available data reveal a complex relationship among chlorine feed, design and operating conditions, and dioxin and furan emissions. It is certain that chlorine sources are necessary for dioxin/furan emissions, PVC products are the largest chlorine source, and incinerators with pollution control equipment are significant sources of dioxin/furan releases in stack gases, fly ash, bottom ash, and water discharges. Moreover, even modern, well-designed incinerators do not consistently operate at optimal combustion conditions. For these reasons, along with concern about other hazardous pollutants emitted from waste incinerators — including mercury, particulates, sulfur and nitrous oxides, and hydrochloric acid — Health Care Without Harm has taken the pollution prevention position that PVC use should be minimized, alternatives used when available without compromising patient safety or care, and all unnecessary waste incineration should be avoided.

## DIOXIN TOXICITY

Rain, snow, and dust bring dioxin and furan emissions to the surface of the earth, often hundreds of miles from their point of origin, where they enter the food chain. Because dioxins and furans are environmentally persistent, bioaccumulative, and fat-soluble, their concentration biomagnifies as they pass up the food chain. Human exposure is primarily through food, with major sources including beef, dairy products, fish, pork, and breast milk.

Dioxins and furans are extremely toxic and potent environmental contaminants. They modulate and disrupt multiple growth factors, hormones, and developmental processes. In animals, dioxin causes cancer in multiple organ systems, sometimes at nanogram/kg body weight exposure levels. Prenatal exposure to dioxin in rodents substantially increases the risk of breast cancer later in life.<sup>18</sup> Human epidemiological studies conclude that dioxin causes cancer in humans as well.<sup>19</sup> The EPA draft dioxin reassessment estimates that as many as one in 1000 of the most highly exposed people in the general population are at risk of developing cancer because of dioxin.

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Dioxin also has widespread effects on reproduction and development, as shown in animal and human studies. Nanogram to microgram/kg body weight doses of dioxin on a single day during pregnancy cause permanent disruption of male sexual development in rodents, including delayed testicular descent, lower sperm counts, and feminized sexual behavior.<sup>20</sup> In primates, small dietary exposures to dioxin are associated with an increased risk and severity of endometriosis.<sup>21</sup> A study in humans also shows higher levels of dioxin in women with endometriosis than in a control population.<sup>22</sup>

Dioxin is particularly toxic to the developing immune system. Animal tests show that nanogram/kg doses given 1-4 times during pregnancy cause permanent alterations in the immune system of offspring.<sup>23</sup> Human studies also show an increased susceptibility to infection and changes in immune system parameters as a result of in utero exposure to ambient environmental levels of dioxin and dioxin-like compounds.<sup>24, 25</sup> Low levels of exposure during pregnancy also alter thyroid hormone levels in mothers and offspring, perhaps explaining neurological effects, including learning disabilities, that are seen in carefully conducted primate studies.<sup>26</sup>

It is of particular concern that the general population, through ordinary dietary exposures, carries a current body burden of dioxin that is near or above the levels that cause adverse effects in animal tests. Moreover, breast milk contamination is such that the nursing infant, during vulnerable periods of development, is exposed to dietary levels of dioxin as much as 60-100 times that of adult exposures. Nonetheless, breast feeding remains far superior to formula feeding for a variety of reasons, and reducing breast feeding is not the appropriate public health response to a contaminated food supply. Rather, all possible steps should be taken to reduce breast milk levels of this contaminant by eliminating releases of dioxin to the environment.

## SOLUTION:

### ESTABLISH AND IMPLEMENT A PVC REDUCTION PROGRAM

Reducing PVC use in hospitals will involve educating staff on the need for change, gathering data, planning, assessing alternatives, and changing procurement policy. Specific steps include:

- establish a PVC reduction policy,
- educate staff on the lifecycle hazards of PVC and the toxicity of DEHP,
- collect data on PVC use in the hospital through audits and letters to vendors,
- identify PVC-free and DEHP-free alternatives, and
- develop and implement a PVC reduction plan.

### *Establish a PVC Reduction Policy*

An organization wide PVC reduction policy is an important step towards reduction because it reflects senior management's support for action, signals staff to take the issue seriously, and signals vendors to market PVC-free products. The Tenet Healthcare and Universal Health Services memoranda of understanding with shareholders on reducing PVC use offer examples of model PVC reduction policy language (see Appendices 2 and 3).

Tenet Healthcare, for example, agreed to: "investigate the availability and utility of PVC-free and phthalate-free disposable medical products available in the marketplace"; "seek information on a regular basis from its suppliers of disposable medical products concerning whether their products are PVC-free and phthalate-free"; and "request its suppliers of disposable medical

products to aid in the development of and further advancements in PVC-free and phthalate-free disposable medical products.”

### **Educate Staff**

Educational programs raise staff awareness of the hazards associated with PVC and DEHP-containing products and establish the reasons why staff should be concerned with the use of these products. Workshops, grand rounds, and conferences are all appropriate forums for promoting awareness of the life cycle hazards of PVC and toxicity of DEHP.

### **Collect Data**

Data collection through audits and letters to vendors is a critical step because reducing PVC requires knowledge of its use and availability of alternatives. Catholic Healthcare West, for example, requires its group purchasing organization (GPO) to identify products that contain PVC. The principal end uses for PVC products in a hospital are:

- disposable health care products,
- office supplies,
- durable medical products (such as testing and diagnostic equipment),
- construction products, and
- furniture products and furnishings (see Appendix 1 for specific products).

PVC products range from critical healthcare devices, such as disposable intravenous (IV) bags and tubing, to bedpans and notebook binders, as well as basic construction materials and furnishings, such as water pipes and wall coverings.

### **Identify PVC- and DEHP-free Alternatives**

Disposable PVC health care products divide into five broad categories: bags, tubes, gloves, trays,<sup>27</sup> and catheters. Bags (42.5%), tubes (43.0%), and gloves (12.5%) account for 98% of disposable PVC healthcare products.<sup>28</sup>

A rigid plastic by nature, manufacturers add DEHP to make PVC flexible. DEHP-free PVC medical devices contain alternative softening agents (plasticizers). Non-PVC plastics used in medical devices, such as silicone, polyethylene, or polypropylene, are inherently flexible and do not contain plasticizers. Thus potential risks from plasticizer leaching are avoided.

Citrates and trimellitates have been substituted for DEHP as plasticizers in PVC medical products. Both may leach from PVC, although at different rates, depending on the nature of the solution in the bag. Citrates are less hazardous than DEHP, as indicated by their use as a food additive. Much less is known about the safety/hazards of the trimellitates, though some research indicates that trimellitates leach less than DEHP.<sup>29,30</sup>

PVC bags package IV products, total parenteral nutrition (TPN) and enteral feeding formulas, and blood products (including packed red blood cells, fresh frozen plasma, and platelet rich plasma). PVC bags are also used to collect some bodily fluids. DEHP-containing PVC medical bags first became a matter of concern in the 1970s because of DEHP exposures from the use of blood and TPN bags. This concern led to the development of PVC-free platelet rich plasma bags, fresh frozen plasma bags, and TPN bags as well as a DEHP-free packed red blood cell bag.

Today, PVC-free bags are on the US market for all but one product, packed red blood cells. The PVC-free bags are cost- and technically-competitive with the PVC bags. For the packed red blood cells, a DEHP-free bag is on the market at a slightly higher cost than the PVC, DEHP bag. An unintended consequence of DEHP leaching from PVC bags is it acts as a preservative of red blood cells. DEHP extends the shelf-life of stored red blood cells by stabilizing the red blood cell membrane. The Food and Drug Administration does not regulate DEHP as an additive to red blood cells. The alternative plasticizer used in red blood cell bags is a citrate. Citrates, in fact, have a long history of use as a blood preservative. The shelf-life of blood in citrate-plasticized bags is similar to that of DEHP-plasticized bags.

PVC tubing conveys liquids — such as IV solutions and enteral formula — and gases — usually oxygen — to and from patients. PVC-free or DEHP-free tubing is on the US market for most medical applications. Silicone, polyethylene, and polyurethane are three alternative polymers frequently used in tubing applications. In most applications, at least one of these polymers can compete with PVC in terms of technical performance.

In fact, PVC tubing and catheters are actually poor technical performers in medical treatments that involve contact with human tissue longer than about three to

seven days. The leaching of DEHP not only exposes patients to the plasticizer, but also causes the product to become brittle and subject to cracking. For these reasons products like umbilical vessel catheters and gastrostomy tubes are no longer manufactured from PVC. Recent research suggests that significant levels of DEHP may leach out of nasogastric tubes within 24 hours. An analysis by researchers at Stockholm University of PVC nasogastric tubes used for 24 hours “showed that the section of the tube which had been inside the infant’s stomach contained only half as much plasticiser as the rest of the tube. Since this discovery, the [Swedish County] council’s medical board decided to substitute polyurethane tubes for the PVC ones.”<sup>31</sup>

In terms of economic performance, PVC-free tubing generally costs more than PVC tubing. In the next few years, however, plastics industry analysts expect metallocene polyolefins (polyethylene and polypropylene are polyolefins) to become cost-competitive with flexible PVC medical products.<sup>32</sup>

Alternatives for disposable **PVC gloves** are also readily available. PVC is used primarily in the manufacture of examination gloves and has little market share in the surgical glove market. Latex is the other dominant material used in the manufacture of examination gloves. However, concerns with latex allergies have led hospitals and manufacturers to consider gloves made of different materials. For example, when Kaiser Permanente decided to phase-out the use of latex gloves it searched for PVC-free gloves, ultimately settling on gloves made of nitrile. While these are more expensive than latex and PVC gloves, Kaiser received a cost-competitive bid due the size of its contract. Reflecting growing demand, a diversity of latex- and PVC-free gloves are on the market today, although costs are slightly higher.<sup>33</sup>

Given the availability of technically-competitive and often cost-competitive alternatives, and the hazards posed by DEHP, Lois Ember of Chemical & Engineering News concluded that:

“Balancing the slight harm to the vinyl chloride industry and the availability of cost-effective alternatives against studies — albeit ambiguous — that show potentially harmful health effects to humans dictates a prudent switch to non-PVC, DEHP-free alternatives.”<sup>34</sup>

The environmental and human health advantages of most flexible, PVC-free medical devices are they do not contribute chlorine to incinerators and do not use plasticizers.<sup>35</sup> See Appendix 4 for a list of PVC- and DEHP-free health care products.

**PVC-free construction and furnishing products** are widely available and are often cost-competitive. For example, PVC-free mattress covers and shower curtains are widely available and are cost-competitive with the PVC products. During renovations and new building construction, hospitals should specify PVC-free products. Construction productions, furnishings, and furniture products account for approximately 75% of all PVC end uses (see the Paper on Green and Healthy Buildings).

### *Develop and Implement a PVC Reduction Plan*

A PVC reduction plan should include the following priorities:

1. first, target **disposable healthcare products**, especially within maternity departments, NICUs, and pediatrics, and **office supplies** for PVC elimination;
2. second, purchase PVC-free **furnishings, furniture products, and construction** products when purchasing new furniture, renovating existing departments, or constructing new wings or buildings; and
3. third, when buying new **durable medical products**, specify those that are PVC free.

These reduction priorities are based on the potential for patient exposure to DEHP, potential for the PVC product to be incinerated upon disposal, volume of PVC use, and availability of substitute products.

**Disposable PVC healthcare products** should be the first priority because of the potential for significant patient exposure to DEHP and because they may be incinerated at the end of their useful life. DEHP exposure is critical to consider, especially for fetuses, newborns, and toddlers who may be exposed to levels of DEHP known to cause harm in relevant animal models. Since DEHP is a reproductive and developmental toxicant, DEHP use in maternity departments, NICUs, and pediatrics is of particular concern. For maternity departments, NICUs, and pediatrics, healthcare providers may decide that eliminating DEHP exposures in their particularly vulnerable patients justifies the higher cost for polyethylene, polyurethane, or



silicone tubing. While purchasing DEHP-free PVC products is an option for reducing DEHP exposure, it should only be considered an interim solution because it does not address the life cycle impacts of PVC (see Appendix 5 for a discussion of DEHP reduction options).

**Office supplies** are another priority for elimination because they may be incinerated upon disposal, cost-competitive alternatives are widely available, and hospitals usually can replace them easily under existing contracts.

**PVC furnishings, furniture products, and construction products** should be eliminated from new purchases, building renovations, and new building construction. For most of these products, cost-competitive, PVC-free alternatives are widely available<sup>36</sup> (for more details, see the paper on Green and Healthy Buildings).

**Durable medical products** pose the greatest challenge to reduction due to the lack of knowledge of their PVC content and availability of PVC-free devices. The primary use for PVC in durable medical products is as the housing — the rigid, outer plastic covering — for testing and diagnostic equipment. Since durable medical products have a longer use life than disposable medical products (such as IV bags) and result in little DEHP exposure, they are a secondary target for reduction. A first step in reducing PVC use in these applications would be to require vendors to disclose the PVC content in their equipment.

## BARRIERS TO PVC REDUCTION

The primary obstacles to reducing PVC use are:

- lack of knowledge of PVC lifecycle hazards, hospital use of PVC, and the availability of PVC-free products;
- the “grandfathering” of medical products on the market prior to 1976;
- contracts, multi-year, single buyer, and bundled;
- limited number of PVC-free vendors;
- costs of transition and alternatives; and
- market opposition to change.

### *Lack of Knowledge*

Most hospital staff are unfamiliar with the life cycle hazards of PVC, the extent to which they use PVC and

DEHP-containing products, and the availability of those that are PVC-free, limiting demand for alternatives. In Europe, where awareness of the life cycle hazards of PVC is greater than in the US, demand for PVC-free products is greater.

### *The ‘Grandfather’ Clause*<sup>37</sup>

Marketing a new medical device requires approval of the Food and Drug Administration (FDA). However, a product that is “substantially equivalent” to devices marketed before May 28, 1976 avoids this strict regulatory scrutiny. The FDA does not require extensive testing of materials used to manufacture medical devices as long as the formulation does not substantially differ from that used prior to 1976. This procedure is not based on a scientific assessment of safety (testing). Rather, it is based on a Congressionally imposed presumption — as stated in section 510(k) of the Food, Drug and Cosmetics Act, as modified by the Medical Device Amendment of 1976 — that products and formulations on the market as of 1976 are presumed safe until proven unsafe. The burden is on the FDA to prove that such medical devices are unsafe before taking regulatory action.

Unfortunately, the law’s grandfathering provision has the effect of discouraging companies from innovating in product formulations. Under existing policies, manufacturers attempt to show that products are made of pre-1976 formulations, since any deviation from traditional product formulas requires more premarket testing and leads to more extensive FDA oversight. A product made of a new polymer would be required to undergo substantial premarket evaluation.

### *Contracts*

To achieve lower per unit product costs, most hospitals purchase medical products through group purchasing organizations (GPOs). GPOs enjoy economies of scale because of large volume purchases, commit to buy for the long-term (up to eight years), and occasionally agree to “bundled” contracts.

Purchasing through GPOs, however, may reduce purchasing flexibility and create impediments to innovation. By locking into long-term contracts with one vendor, GPOs — and the hospitals they represent — cannot change to another vendor before a contract expires without incurring a significant monetary penalty. Long-term contracts block immediate access to vendors of PVC-free products. For example, of the

three US market leaders in IV products,<sup>38</sup> only B. Braun McGaw markets a PVC-free bag. If a hospital decides it wants to purchase a PVC-free IV bag (and all the accompanying IV products), and its GPO has a long-term contract with Abbott Laboratories or Baxter Healthcare, it cannot purchase the PVC-free IV bag without incurring a monetary penalty.

The industry-wide practice of bundling contracts — where a vendor reduces the price of one product line if a buyer purchases another product line — further ties the hands of purchasers. For example, by switching to a different IV product manufacturer, a buyer may incur greater costs for pharmaceutical products, resulting in a net increase in expenditures.<sup>39</sup> Thus bundling and long-term contracts impede innovation by creating market barriers to new products.

The options available to healthcare organizations locked into long-term contracts include clearly stating their desire for PVC-free products to both their GPO and current vendors and finding individual departments within the hospital where product change is possible, such as NICUs. When contracts expire, healthcare organizations need to voice their desire to GPOs that they want a) single source contracts with manufacturers of PVC-free products or dual source contracts that include a vendor of PVC-free products and b) a clause added to new contracts that allows them to switch to products with better environmental performance.

### ***Limited Number of PVC-Free Vendors***

PVC-free products are on the US market in many product categories. However, the number of vendors of PVC-free products within each category may be limited. This is the case with both PVC-free IV bags (as noted above in the “Contracts” section) and PVC-free enteral feeding bags, where only one vendor sells the PVC-free product. The scarcity of vendors selling PVC-free products in the US is in sharp contrast to Europe. For example, at least seven corporations manufacture PVC-free IV bags in Europe,<sup>40</sup> whereas only one manufactures PVC-free IV bags in the US. At least four corporations manufacture PVC-free IV tubing in Europe, whereas none manufacture it in the US.

Corporations that sell in both the European and US markets often choose not to market PVC-free products in the US. Baxter International sells PVC-free IV bags in Europe, but not in the US.<sup>41</sup> B. Braun McGaw,

whose corporate parent (B. Braun) markets PVC-free IV tubing in Europe, does not sell PVC-free IV tubing in the US. Fresenius sells a PVC-free peritoneal dialysis system in Europe, but not in the US. The combination of limited numbers of PVC-free vendors and long-term contracts can limit opportunities for a hospital to purchase a PVC-free product in the US (without incurring a monetary penalty for breaking a contract).

### ***Costs***

The potential monetary costs of product change come in two forms: transition costs for employees and potentially higher costs for alternative products. For some products, switching vendors requires training in the use of new equipment. The costs for some PVC-free products may be higher in the short-term but decline in the long-term, as costs of alternatives decrease with improved efficiency in production and through economies of scale.

### ***Market Opposition***

Transitioning away from PVC products is made more difficult by the vocal opposition of vested economic interests and their allies. Manufacturers with direct economic interests in continued PVC use include DEHP manufacturers, manufacturers involved in any stage of PVC production, and medical device manufacturers. Trade associations that have expressed support for continued PVC and DEHP use in healthcare include the American Chemistry Council (trade association of the chemical industry), AdvaMed (trade association for medical device manufacturers), and the Vinyl Institute. Think tanks that have expressed support for continued PVC and DEHP use in healthcare include the American Council on Science and Health, Competitive Enterprise Institute, and Reason Public Policy Institute.

Any hospital or healthcare organization that publicly announces a PVC reduction program should expect a visit from a trade association such as the Vinyl Institute or a manufacturer of PVC medical products. The broad arguments against the transition away from PVC and DEHP products are: 1) PVC incineration does not correlate with dioxin emissions and 2) DEHP is safe for use in healthcare products.

PVC advocates rely on the report by Rigo, et al to support their conclusion that PVC combustion does not correlate with dioxin production. This report, as discussed in endnote, has serious methodological flaws.

Other data support a correlation between PVC combustion and dioxin emissions (see "PVC, Dioxin, and Health-Care Institutions" above for more details).

DEHP advocates rely on reports by the American Council on Science and Health (the "Koop Report"),<sup>42</sup> Competitive Enterprise Institute,<sup>43</sup> and Reason Public Policy Institute to support their claim that DEHP is safe for use in medical products.<sup>44</sup> These reports conclude, as succinctly stated in the Koop Report, that "DEHP in medical devices is not harmful to even highly exposed people" (p. 2). The basis for this conclusion, as Schettler revealed in a letter-to-the-editor of Medscape, is a selective review of the scientific literature.<sup>45</sup>

When all the scientific literature relevant to DEHP toxicity and exposure was evaluated by the independent Expert Panel on Phthalate Esters from the National Toxicology Program's Center for the Evaluation of Risks to Human Reproduction, conclusions that differed dramatically from the Koop Report were reached. As noted above in "Patient Health and Safety," the panel expressed "serious concern that exposure [to critically ill infants from medical devices] may adversely affect male reproductive tract development."<sup>46</sup>

## CONCLUSION

PVC products pose two potentially significant hazards to humans across their life cycle. First, the use of PVC products in medical treatments may result in patient exposure to DEHP, a reproductive and developmental toxicant. Concerns about other potential health effects remain unresolved. Second, the production of PVC and its disposal in incinerators contribute to the formation and emission of dioxins and furans, extremely toxic and potent environmental toxicants.

Health care providers can change the material composition of products and can reduce the use of PVC by demanding safer and cleaner products. The availability of PVC-free umbilical vessel catheters, TPN bags, platelet rich plasma bags, and fresh frozen plasma bags, and DEHP-free packed red blood cell bags are all examples of how the market shifted when health care providers voiced concerns in the 1970s. The medical product market is shifting once again, especially in Europe where PVC-free bags and tubing are widely available. Some manufacturers have chosen to market PVC-free products in Europe, yet continue to sell the

PVC products in the US. The US market shows signs of incremental change, as indicated by Baxter's decision to market PVC-free IV bags in the near future. However, without a clear signal from health care providers that they want PVC-free products, manufacturers will continue to delay the introduction of these products in the US.

## RESOURCES

**European Commission. 2000.** Green Paper on Environmental Issues of PVC.

Webpage: <http://www.europa.eu.int/comm/environment/pvc/index.htm>

**European Commission. 2000.**

Five PVC studies:

1. The Influence of PVC on the Quantity and Hazardousness of Flue Gas Residues from Incineration
2. Economic Evaluation of PVC Waste Management
3. The Behaviour of PVC in Landfill
4. Chemical Recycling of Plastics Waste (PVC and Other Resins)
5. Mechanical Recycling of PVC Wastes

Webpage: [http://www.europa.eu.int/comm/environment/waste/facts\\_en.htm](http://www.europa.eu.int/comm/environment/waste/facts_en.htm)

National Toxicology Program, Center for the Evaluation of Risks to Human Reproduction (CERHR). 2000. NTP CERHR Expert Panel Report on Di (2-ethylhexyl) Phthalate. Webpage: <http://cerhr.niehs.nih.gov/news/index.html>.

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US EPA. 2000. Draft Exposure and Human Health Reassessment of 2,3,7,8-Tetrachlorodibenzo-p-Dioxin (TCDD) and Related Compounds. Webpage: <http://www.epa.gov/ncea/pdfs/dioxin/part1and2.htm>.

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## ENDNOTES

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6. See the National Toxicology Program's webpage: <http://cerhr.niehs.nih.gov/news/index.html>.
7. Loff S, Kabs F, Witt K, et al. Polyvinylchloride infusion lines expose infants to large amounts of toxic plasticizers. *J Pediatr Surg* 35:1775-1781, 2000.
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10. See US EPA, Report #: EPA/600/P-00/001Ab, March 2000
11. The EPA developed a three-part confidence rating scheme: "high" means the estimate is derived from a comprehensive survey; "medium" is based on estimates of average activity and

number of facilities or a limited survey; and "low" is based on data judged possibly non-representative.

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37. The source for this section is: Health Care Without Harm, "Citizen Petition before the United States Food and Drug Administration," June 14, 1999 (Falls Church, VA: Health Care Without Harm).
38. The three market leaders are Abbott Laboratories, Baxter Healthcare, and B. Braun McGaw.
39. Another cost of change, discussed below, is transition costs for staff training.
40. See Lichtman, B, *Flexible PVC faces stiff competition*, European Medical Device Manufacturer, March/April, 2000; Rossi M and Muehlberger M, *Neonatal Exposure to DEHP and Opportunities for Prevention in Europe*, 2000 (Falls Church, VA: Health Care Without Harm); and The Federation of Swedish County Councils, 2000, *PVC in the Swedish Healthcare System*, Stockholm.
41. While Baxter has committed to bringing a PVC-free IV bag to market in the US, it has yet to do so.
42. Koop CE and Juberg DR, "A Scientific Evaluation of Health Effects of Two Plasticizers Used in Medical Devices and Toys: A Report from the American Council on Science and Health," Medscape, June 22, 1999, [www.medscape.com/Medscape/GeneralMedicine/journal/1999/v01.n06/mgm06222.koop/mgm06222](http://www.medscape.com/Medscape/GeneralMedicine/journal/1999/v01.n06/mgm06222.koop/mgm06222).
43. Durodié B, *Poisonous Propaganda*, Washington, DC: Competitive Enterprise Institute, 1999.
44. Green K, *Phthalates and Human Health: Demystifying the Risks of Plastic-softening Chemicals*, Washington, DC: Reason Public Policy Institute, 2000.
45. "For example, the panel notes that the target organ for reproductive toxicity in the rat appears to be the testis and that young animals seem to be more sensitive than older animals. Inexplicably, however, the authors then fail to cite a single, readily available study of the effects of DEHP exposure on fetal or neonatal testes. Unmentioned are at least 4 studies demonstrating the particular sensitivity of the immature developing testis to the toxicity of DEHP." Schettler T, "Letter in Response to ACSH Report on Plasticizers," Medscape ([www.medscape.com](http://www.medscape.com)), May 26, 2000.
46. Page 105.

## APPENDIX 1.

### POLYVINYL CHLORIDE (PVC) PRODUCTS IN HOSPITALS

#### *Disposable Health Care Products*

##### **BLOOD PRODUCTS AND TRANSFUSIONS**

- apheresis circuits
- blood bags
- blood administration tubing
- extracorporeal membrane oxygenation circuits

##### **COLLECTION OF BODILY FLUIDS**

- dialysis, peritoneal: drainage bags
- urinary collection bags, urological catheters, and irrigation sets
- wound drainage systems: bags and tubes

##### **ENTERAL FEEDING PRODUCTS**

- enteral feeding sets (bags and tubing)
- nasogastric tubes, short-term use (usually for neonates)
- tubing for breast pumps

##### **GLOVES, EXAMINATION**

##### **INTRAVENOUS (IV) THERAPY PRODUCTS**

- catheters
- drip chambers
- solution bags
- total parenteral nutrition bags
- tubing

##### **KIDNEY (RENAL DISEASE) THERAPY PRODUCTS**

- hemodialysis: blood lines (tubing) and catheters
- peritoneal dialysis: dialysate containers (bags) and fill and drain lines (tubing)

##### **PACKAGING, MEDICAL PRODUCTS**

- film wrap
- thermoformed trays for admission and diagnostic kits, and medical devices

##### **PATIENT PRODUCTS**

- bed pans
- cold and heat packs and heating pads
- inflatable splints and injury support packs
- patient ID cards and bracelets
- sequential compression devices

#### *Disposable Health Care Products (continued)*

##### **RESPIRATORY THERAPY PRODUCTS**

- aerosol and oxygen masks, tents, and tubing
- endotracheal and tracheostomy tubes
- humidifiers, sterile water bags and tubing
- nasal cannulas and catheters
- resuscitator bags
- suction catheters
- ventilator breathing circuits

#### *Office Supplies*

- notebook binders
- plastic dividers in patient charts

#### *Durable Medical Products*

- testing and diagnostic equipment, including instrument housings

#### *Furniture Products and Furnishings*

- bed casters, rails, and wheels
- floor coverings
- furniture upholstery
- inflatable mattresses and pads
- mattress covers
- pillowcase covers
- shower curtains
- thermal blankets
- wallpaper
- window blinds and shades

#### *Construction Products*

- doors
- electrical wire sheathing
- pipes: water and vent
- roofing membranes
- windows

**APPENDIX 2.**  
**TENET HEALTHCARE CORPORATION, MEMORANDUM OF  
UNDERSTANDING WITH SHAREHOLDERS**

**LETTER AGREEMENT CONCERNING SHAREHOLDER PROPOSAL**

This Letter Agreement Concerning Shareholder Proposal is entered into as of July 22, 1999, among the Sisters of St. Francis, Medical Mission Sisters and SEIU Master Trust (collectively, the "Shareholders") and Tenet Healthcare Corporation (together with its subsidiaries, "Tenet"). As used herein, Tenet includes the operations of BuyPower, Tenet's group purchasing operation.

**RECITALS**

- A. Between April 30, 1999, and May 3, 1999, each of the Shareholders submitted an identical shareholder proposal (the "Shareholder Proposal") to Tenet requesting the Board of Directors of Tenet to adopt a policy of phasing out, at all of its health care facilities, the use of polyvinyl chloride ("PVC")-containing or phthalate-containing medical products, where alternatives are available.
- B. Tenet is committed to conducting its business in a socially responsible and ethical manner that protects the safety of its patients and employees as well as the environment. Tenet recognizes that PVC plastic, a component of various medical products, may result in damage to the environment.

**AGREEMENT**

1. Tenet hereby agrees to investigate the availability and utility of PVC-free and phthalate-free disposable medical products available in the marketplace and periodically will review the state of the availability and utility of alternative products as technological advances result in the production of disposable medical products that do not contain PVC or phthalates. Tenet agrees to ask its top 25 suppliers about the availability of new medical products that do not contain PVC or phthalates at least twice a year and to report to back the Shareholders at least twice a year on the results of Tenet's inquiry.
2. Tenet will develop an environmentally preferential purchasing policy for PVC-free and phthalate-free disposable medical products and utilize such products to the extent they are of a high quality, are of the same or better functionality as the products being replaced and are readily and reliably available at a reasonable price. Tenet further agrees to notify its vendors concerning its policy. Notwithstanding the foregoing, however, although Tenet will use its reasonable efforts to amend its supply contracts to allow Tenet to use alternative products that meet the above criteria, Tenet shall not be required to use alternative products if doing so violates the terms of such contracts. To the extent possible on commercially reasonable terms, Tenet will use its reasonable efforts to include in its future purchasing contracts a clause allowing Tenet to cease purchasing medical products containing PVC or phthalates under such contracts if there become readily and reliably available at a reasonable price alternative PVC-free and phthalate-free disposable medical products that are of the same or better functionality as the products being replaced.
3. Tenet will seek information on a regular basis from its suppliers of disposable medical products concerning whether their products are PVC-free and phthalate-free and concerning the availability of alternative products.
4. Tenet will request its suppliers of disposable medical products to aid in the development of and further advancements in PVC-free and phthalate-free disposable medical products.

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3. Tenet will seek information on a regular basis from its suppliers of disposable medical products concerning whether their products are PVC-free and phthalate-free and concerning the availability of alternative products.
4. Tenet will request its suppliers of disposable medical products to aid in the development of and further advancements in PVC-free and phthalate-free disposable medical products.
5. A representative or representatives of Tenet will be happy to meet with a representative or representatives of the Shareholders by no later than January 31, 2000, at a mutually convenient time and place, to discuss Tenet's progress in achieving the goals set out in this Agreement and to further address the concerns expressed by the Shareholder Proposal.
6. In light of the terms of this Agreement, each of the Shareholders hereby withdraws its request that Tenet



**APPENDIX 3.**  
**UNIVERSAL HEALTH SERVICES,**  
**MEMORANDUM OF UNDERSTANDING WITH SHAREHOLDERS**

Universal Health Services ("UHS") is committed to conducting its business in a socially responsible and ethical manner, which protects patient and employee safety and the environment. UHS recognizes that polyvinyl chloride ("PVC") plastic, a component in various medical products, may result in damage to the environment. In light of these factors and in conjunction with a proposed shareholder resolution filed with the Company on December 21, 1998, UHS plans to investigate the utilization of PVC-containing items in their operations through the following measures:

- 1) The Company will investigate the availability and utility of PVC-free products available in the marketplace and will periodically continue its investigation as technological advances provide cost effective and high quality products. To aid in this process, Health Care Without Harm will provide UHS a list of items potentially containing PVC. Utilizing this information, the company will review its current supplies and request PVC-free alternatives from its suppliers, where appropriate.
- 2) To the extent that it is consistent with high quality and cost effective health care delivery, UHS will continue to explore the use of PVC-free products and utilize such products to the extent they are available. UHS agrees to formally request PVC-free alternatives from its suppliers to aid in the development of further advancements in PVC-free products.
- 3) The Company agrees to meet with representatives of the filing shareholders and Health Care Without Harm prior to June 30, 1999 in order to establish the timetable and benchmarks for the items listed above. UHS agrees to meet with the filing shareholders and other mutually agreed upon parties prior to October 31, 1999 to assess the Company's progress.

The Company and the filing shareholders agree to announce this agreement through a mutually agreed upon joint press release to be distributed on May 19, 1999 in conjunction with the UHS Annual Meeting. The Company's willingness to enter into this agreement furnishes the filing shareholders the sufficient evidence of goodwill on the Company's behalf to allow the removal of the shareholder resolution from the Company's proxy for the upcoming Annual Meeting. The filing shareholders hereby withdraw the shareholder resolution from the company's proxy.

UNIVERSAL HEALTH SERVICES, INC.

CITIZENS FUNDS

On Behalf of Filing Shareholders

By: \_\_\_\_\_

Name: Kirk E. Gorman

Title: Senior Vice President, Chief Financial  
Officer and Treasure

Date: April 19, 1999

By: \_\_\_\_\_

Name: Samuel Pierce

Title: Senior Social Research Analyst

Date: April 19, 1999

# APPENDIX 4. PVC- AND DEHP-FREE DISPOSABLE HEALTH CARE PRODUCTS

PRODUCTS	PVC-FREE PRODUCTS	DEHP-FREE PRODUCTS
<b>Blood Products, Transfusions, and Extracorporeal Membrane Oxygenation (ECMO)</b>		
Apheresis Circuit		Citrate-plasticized circuit: Cobe
ECMO Circuit		None on the market, although the Cobe apheresis circuit is technically equivalent
Fresh Frozen Plasma and Platelet Bags	PO bag: Baxter Healthcare	
Packed Red Blood Cell Bag		Citrate-plasticized bag: Baxter Healthcare
<b>Collection of Bodily Fluids</b>		
Drainage Bags	PO bag: Dow Chemical Corp. (manufacturers films for use with drainage bags)	
<b>Dialysis Products</b>		
Hemodialysis, Blood Circuits		None on the market, although the Cobe apheresis circuit is technically equivalent
Peritoneal Dialysis, Bags and Tubing	Europe: PVC-free bags & tubing, Fresenius & B. Braun Japan: PVC-free bags, Terumo	
<b>Enteral Feeding Products</b>		
Enteral Feeding Set: Bags	Nylon, EVA, PE laminate bag: Corpak MedSystems	Kendall Healthcare
Enteral Feeding Set: Tubes		Corpak and Kendall Healthcare
Nasogastric Tubes (for 3 days or less)	Similar product: indwell tubes made from PUR or silicone, many manufacturers	
<b>Gloves</b>		
Examination Gloves	Nitrile or other polymers: many manufacturers	
<b>Intravenous (IV) Products</b>		
IV Bags	PP/PE copolymer, polyester, elastomer laminate bag: B. Braun McGaw	
IV Tubing	Europe: EVA or PO, many manufacturers	Budget Medical Products
Total Parenteral Nutrition	EVA bag: Baxter Healthcare	
<b>Packaging, Medical Devices</b>		
Trays for Admission and Diagnostic Kits, and Surgery	Acrylic, polycarbonate, polyester, polystyrene, steel: many manufacturers.	
<b>Respiratory Therapy Products</b>		
Endotracheal and Tracheostomy Tubes	Reusable tubes: many manufacturers; Silicone tube: Biovana Medical Technologies	
Oxygen Masks	Polyester mask: Vital Signs	

Abbreviations: DEHP = di-2-ethylhexyl phthalate; EVA = ethylene vinyl acetate; PE = polyethylene; PO = polyolefin; PP = polypropylene; PUR = polyurethane; and PVC = polyvinyl chloride. Blank cell: no PVC-free or DEHP-free alternative product identified. Sources: The Federation of Swedish County Councils, PVC in the Swedish Healthcare System, 2000; Rossi, Neonatal Exposure to DEHP and Opportunities for Prevention, 2000; Rossi and Muehlberger, Neonatal Exposure to DEHP and Opportunities for Prevention in Europe, 2000; Sustainable Hospitals Project, [www.sustainablehospitals.org](http://www.sustainablehospitals.org).

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## APPENDIX 5.

### DEHP REDUCTION OPTIONS

There are three routes for healthcare facilities to reduce or eliminate DEHP exposure from medical treatments. First, purchase a PVC-free product. Second, purchase a DEHP-free product. Third, purchase a DEHP-plasticized PVC product coated with an alternative substance to reduce DEHP leaching or off-gassing. Purchasing a PVC-free product practically ensures the product is DEHP-free because the alternative polymers — ethylene vinyl acetate, polyethylene, polypropylene, polyurethane, and silicone — do not require plasticizers for flexibility. In addition, PVC-free products avoid the life cycle hazards of PVC, including the use of a known carcinogen in the manufacturing process, vinyl chloride monomer, and the downstream formation of dioxin when vinyl is burned in a medical waste incinerator.

Using a PVC product plasticized with citrates or trimellitates, the primary alternative plasticizers to DEHP in medical products, reduces DEHP exposure but does not address the life cycle hazards of PVC. One option for reducing DEHP exposures is to use DEHP-plasticized PVC products coated with a thin layer of another material that prevents or reduces DEHP leaching. For example, PVC tubing bonded with heparin leaches less DEHP during ECMO than unbonded tubing.<sup>1</sup> While preferable to non-coated DEHP-plasticized vinyl, DEHP-coated products do not address off-gassing nor do they address the life cycle hazards of PVC.

1. Karle V, Short B, Martin G, et al. Extracorporeal membrane oxygenation exposes infants to the plasticizer, di(2-ethylhexyl)phthalate. Crit Care Med 25(4):696-703, 1997.



## PVC Plastic: a Looming Waste Crisis

### PVC Recycling - Solving a Problem or Selling a Poison?

*PVC has been under severe pressure since the 1980s, on environmental grounds. In order to maintain its market position, the PVC industry has had to react against this pressure, and it therefore launched a public campaign to "green" PVC, with recycling at its centre.*

The role of recycling in "greening" the PVC industry is best illustrated by the leaked minutes of a Solvay meeting held in Brussels in 1990. The minutes state: "After, M. Brouillot, a trade union representative remarked that this project (PVC recycling) is not economically viable. It is necessary, however, for its publicity and educational value". M. Bonny, a senior manager, added that the PVC recycling operation is 'for enhancing the public profile of PVC which is now under frequent attack' (Solvay 1990). Another leaked Solvay document, dated April 1992, outlines a strategy for a proposed public relations campaign to restore the image of PVC. This strategic plan includes recycling demonstrations, reports, workshops, conferences and a "media attack on journals read by opinion leaders" as a key strategy (Solvay 1992).

This strategy, as outlined by Europe's market leader in PVC, Solvay, seems to be a guiding principle for the industry world-wide. The industry is involved in all major PVC recycling schemes, and claims that they demonstrate PVC can be, and is being, recycled: "The steadily increasing number of PVC recycling projects around Europe, however, provide a very adequate demonstration that PVC can be recycled as safely and as readily as the other commodity plastics" (Norsk Hydro 1995). "PVC can readily be recycled, and can also be separated from mixed plastic wastes" (PACIA 1996). "Demand for recycled vinyl far outstrips supply" (Vinyl Institute 1993).

This recycling "strategy" seems to be paying off for the PVC industry. Governments, local authorities, PVC product manufacturers and consumers are now involved in recycling projects; in the countries which have the most advanced policies on PVC, like Germany, Denmark, the Netherlands and Austria, recycling is the centrepiece of these policies. The key role of PVC recycling for decision-makers is illustrated in the Dutch EPA's position on PVC (Zoeteman 1993): "The main feature of this policy is that PVC applications for which no feasible system of recycling and re-use can be established, the use of more environmental-sound alternative material is to be preferred." The Dutch government recently reconfirmed this policy in a PVC position paper (VROM 1997)

But does PVC recycling solve an environmental problem, or is it an empty claim which merely prevents or postpones the adoption of more stringent measures?

This report examines the latest advances in PVC recycling, and analyses the looming PVC waste crisis.

[ [Report Contents](#) ]

## PVC Recycling: a Cycle of Problems

*For safe and useful materials, recycling is a beneficial activity, which governments and industry should promote and undertake. However, in the case of toxic materials, it simply perpetuates the toxic production of environmental poisons. Promotion of PVC recycling is a prime example.*

A distinction should be made between 'post-consumer recycling' - the recycling of used products - and 'pre-consumer recycling' - the recycling of production waste. Pre-consumer recycling can be seen as optimising the efficiency of material use in manufacturing processes, while post-consumer recycling is the popular definition of recycling to conserve resources. Mechanical recycling in this report refers exclusively to post-consumer recycling. However in reality, most of the PVC recycling figures reported include pre-consumer PVC waste, which is recycled in the production process.

The recycling of post-consumer PVC poses particular technical and financial problems. More than half of the mass of pure PVC consists of chlorine, which affects its disposal in general. Final PVC products can also contain up to 60% of additives in all kinds of different combinations, (depending on their application and manufacturer) which also affects their disposal and recyclability. In addition, its melting point makes PVC incompatible in mixed plastics recycling.

PVC has the lowest recycling rate of all commodity plastics. At present, according to the plastics industry, only 6% of all plastics use in western Europe is mechanically recycled (APME 1996b). PVC has the lowest recycling rate of any commonly-used plastic: only 0.6% of consumption in western Europe (Sofres 1995). In the USA, only 0.6% of PVC in packaging is recycled (RW Beck 1996). In the same study, total post-consumer PVC recycling was estimated at 4,300 tonnes in 1995 (RW Beck 1996) - around 0.1% of the total US PVC consumption of approximately 4,300,000 tonnes. In Australia, only 0.25% of PVC consumption is recycled (Bie 1994). The European, US and Australian figures show a lower recycling rate for PVC than for any other of the commonly-used plastics.

PVC is incompatible with the potential recycling of other plastics in mixed plastic recycling. PVC cannot be mechanically recycled with other common thermoplastics like PE and PP (polyethylene and polypropylene) because of the differences in moulding temperatures. The moulding temperature of PVC is between 180 and 210 degrees

centigrade, whereas all the others (PE, PP, PS (polystyrene)) can be processed together within the temperature range of 220 to 260 degrees centigrade (Moller and Jeske 1995). At these temperatures, PVC starts to decompose (a process known as dehydrohalogenation), forming hydrochloric acid (HCl), which is highly corrosive to the equipment. Consequently PVC effectively sabotages the potential recycling of other plastics.

A common problem is the incompatibility of PVC with PET (polyethylene terephthalate) recycling. At the high PET processing temperature of 250 degrees centigrade or above, PVC degrades. If the PET is contaminated with PVC, it will leave black particles in the otherwise clean resin. As little as 20 parts per million - around one PVC bottle for every 50,000 PET bottles - can ruin recycled PET (Nir et al. 1993). PET and PVC cannot be separated by normal flotation methods, because they have similar densities, so special techniques have had to be developed to remove PVC in PET recycling, such as automated sorting based on colour, and detection of the chlorine atom in PVC using X-ray analysis (Nir et al. 1993). PVC thus makes the recycling of PET and other plastics more expensive.

High collection and separation costs. European experience shows that mixtures of lightly and heavily soiled plastic waste containing PVC can only be separated at great expense. This creates, on the one hand, a more or less clean PVC fraction, and on the other, a recyclable fraction of other plastics. In Germany, experience with packaging waste has shown that separation for recycling costs about DM 800 per ton, not including logistical

costs (Menges 1996), which is very expensive. For this reason, PVC recycling basically focuses on products that can be collected separately, such as windows and pipes, and to some extent bottles. It appears, at present, that only PET and HDPE (high density polyethylene) recyclate is of a high enough standard to be used for high quality products. The physical properties of recompounded HDPE may be in the same range as the virgin polymer (Howell 1992). Currently, about 90% of mechanical plastic recycling in Europe involves the polyolefins (PP, PE) and PET. In the USA, PET recycling has been the most successful of all plastics and manufacturers are substituting PET for other resins in a number of packaging products (Nir et al. 1993).

Recycled PVC more expensive than virgin PVC, but lower quality. Recycled PVC from packaging and construction materials is a mixture of different grades, additives, plasticisers, and some fillers. It never achieves the performance given when specifically selected grades and additives are formulated together to meet a well-defined and specific purpose. The market value of recycled PVC will therefore always be well below that of primary PVC (SRI International 1993).

In Germany, the market value of regranulate is roughly 70% that of virgin PVC. But the cost of mechanical recycling (including collection and transportation) is estimated at DM 3-4 per kilogram of PVC, while the cost of virgin PVC fluctuated between DM 1.00 and 1.80 /kg in 1990-1992 (Pohle 1997). This means that in Germany PVC recyclate can only be sold at 70% of the price of virgin PVC even though it is some 200-300% more expensive.

Virgin PVC is mixed with additives to produce materials with physical properties suited to specific applications. There are literally thousands of formulations available (Ehrig 1992). Anyone wishing to use recycled PVC will therefore inevitably require a quality profile that comes as close as possible to that of a specific virgin material. Since this is unlikely to be achieved in practice, two options remain open, depending on the quality of the product (Menges 1996): remelt it directly into 100% recyclate and create products of lower quality with little market value; or mix it with virgin PVC into a compound material. The first option spreads toxic additives into new areas while creating low quality products; the other generally requires the input of large quantities of new material. This is not recycling.

### Downcycling

Direct remelting in the form of 100% recyclate usually results in low quality products. Examples include plastic park benches and bird cages, products which have traditionally been made from other materials. This form of recycling may simply shift the disposal problem into another, more unmanageable waste stream. A good example is the recycling of PVC bottles into pullovers, made of 70% PVC recyclate. This recycling scheme replaces a chlorine-free material with a chlorinated material, with all the associated waste management problems (Pohle 1997). PVC recycling also helps to spread toxic additives into new areas and products. For example, dangerous levels of PCBs, dioxins and other hazardous substances were found in products made from recycled PVC cables, such as bird cages, in Germany in 1994 (Die Zeit 1994).

New markets for downcycling are booming in developing countries. There, plastic scrap is being downcycled into shoes and other short-life products that may end up in the waste stream in a few years' time.

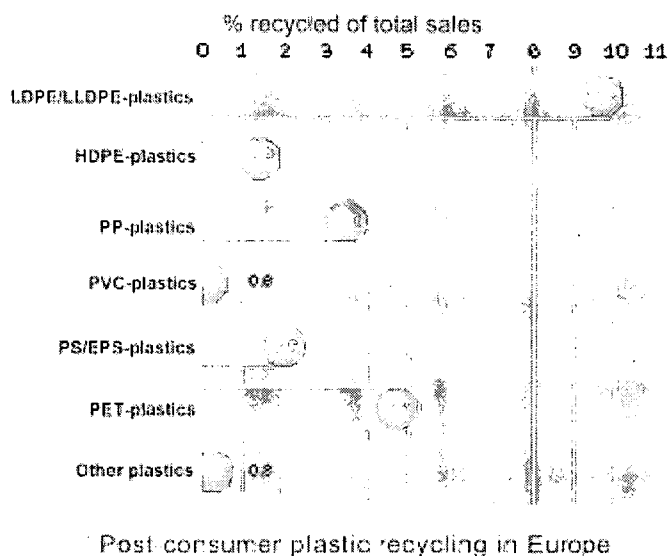
Recycled PVC wrapped up in virgin PVC. To produce high quality products from PVC recyclate, like windows and pipes, virgin PVC is needed. It is therefore highly doubtful whether PVC recycling will result in a decrease in PVC production. Pipes can contain up to 60% of regranulate, according to the industry, and need at least 40% virgin PVC. According to the industry, recycled window frames can contain up to 80% of PVC recyclate from used windows, but need additional virgin PVC to achieve the required quality. However, in practice even this is not happening to any significant degree, as can be seen in the example of the German 'recycled' window frames (see Chapter 4).

Another obstacle for PVC recycling is that old material can contain relatively high levels of additives, such as lead and cadmium stabilisers and PCB's, which would contaminate new products in which those additives

have been reduced or eliminated (SRI International 1993, Kaiser et al. 1993). For this reason, PVC recycling of cables and old windows may be restricted in countries where these additives are regulated, banned or restricted. A prime example is Austria, that does not use post consumer PVC windows regranulate because of the lead and cadmium content of old windows (see next chapter). More additives are likely to be classified as hazardous, such as chlorinated paraffins (OSPAR) and phthalates (Denmark), and this may further restrict the potential for PVC recycling in future.

Chemical recycling - an expensive, polluting and energy consuming attempt to convert plastic waste into raw materials: chlorine in PVC makes it all the more dangerous. Chemical recycling (or feedstock or raw material recycling) of plastics is a growing area of research. The aim is to recycle mixed plastics into hydrocarbons, which are raw material for the petrochemicals industry. The energy used to produce and manufacture the product is destroyed in chemical recycling; therefore, from a energy perspective, it is less advisable than mechanical recycling. Chemical recycling processes take place at high temperatures - 500-900 degrees centigrade - and dioxin may form in some stages if PVC or other chlorine sources are present.

PVC also creates problems in chemical recycling because of the formation of hydrochloric acid. This is corrosive to process equipment and poses a problem when released into the environment. Depending on the facility, the chlorine content in the mixed plastics feedstock may range from parts per million (ppm) up to a few per cent. Also, too much chlorine in the hydrocarbon end product can pose a problem for refineries because it may disrupt catalytic processes (Pohle 1997).



Pyrolysis is a thermal process that takes place at 500-900 degrees centigrade, without oxygen. Mixed plastics can be pyrolysed into hydrocarbons (oil), soot, etc. If PVC is present, hydrochloric acid and chlorinated hydrocarbons are also produced; hydrochloric acid needs to be removed from the pyrolysis gas, but this removal process can result in the formation of dioxins (Pohle 1997). The main end product of pyrolysis is oil for the oil industry. The chlorine content in this end product needs to be kept low - below 10 ppm - otherwise it will disrupt the cobalt/molybdenum catalysts in the refinery. Mixed plastic waste that contains PVC needs to be pre-treated by removing PVC and other halogenated plastics from the feed or by degradative extrusion. However, dioxin formation cannot be excluded and it is expensive (Pohle 1997). Oil from the pyrolysis of soft PVC may contain up to 60% softeners (Pohle 1997).

The only pyrolysis plant currently in use is the Fuji-Recycling pilot plant in Aioi, Japan, with a capacity of 1000 t/a (Pohle 1997). In the hydration process, mixed plastics are reprocessed into hydrocarbons and hydrochloric acid by hydration under pressure of 200-400 bar, at about 500 degrees centigrade. A 90% oil recovery is possible from mixed plastics, which can contain up to 1% PVC (Pohle 1997). According to a rough estimate, the energy balance for PVC may be negative (Pohle 1997).

Chemical recycling is more expensive than mechanical recycling: DM 1.00-1.50 /kg compared to DM 0.70-1.00/kg (excluding logistical costs, Pohle 1997). BASF spent DM 40 million in the development of a pilot plant in Ludwigshafen based on hydration. However, it had to cancel its upgrading because of competition from the steel industry, which uses plastic waste as a chemical reducing agent, to replace fuel at half the price BASF charges (Chemical Week 1996). In December 1996, BASF announced it was calling a halt to the entire project (European Chemical News 1996).

Environmental and worker health impacts of recycling. The hazards associated with mechanical recycling are similar to those for primary plastics processing, which may include air emissions, water discharges and worker exposure. Hydrogen chloride can be released during crushing and grinding of PVC (Kollmann et al. 1990).



More emissions are generated by extrusion-based processes than by those involving injection moulding (Forrest et al. 1995). Elevated levels of dioxins and furans were also found in a German workplace where post-chlorinated PVC was being extruded. The dioxins were thought to originate from the PVC resin (BF Goodrich 1992). However, the few available data indicate that there is a low dioxin formation (0,0001 - 0,037 ng TE/m<sup>3</sup>) in PVC product manufacturing (Länderausschusses für Immissionsschutz 1993). Elevated dioxin levels in soils were also found near four PVC product manufacturers in Baden-Württemberg, though the level of background contamination was not established in this study (LFUBW 1993). However, these are strong indications that these PVC product manufacturing plants may be significant dioxin sources, and more research is needed. It should not be ignored, either, that dioxins can form as a result of overheating during malfunctioning of the recycling processes (Pohle 1997).

In a recent case-control study in Sweden among workers in plastic product manufacturing, an increased risk of testicular cancer was found among PVC workers. Exposure to other plastics than PVC did not significantly increase the risk of testicular cancer (Hardell et al. 1997).

PVC increases toxic emissions in other recycling processes such as steel smelting, car reclamation and cable recycling. PVC can be a source of contamination in the recycling processes of other materials. A Finnish study found that a large amount of chlorinated aromatic compounds - such as dioxins, furans, PCBs and pentachlorophenol - are formed because of PVC plastic in cables and car compounds in metal reclamation (Aittola et al. 1993). From the available data, it can be concluded that, in steel melting processes, dioxin emissions increase as contamination from chlorinated compounds (of which PVC was identified as a significant source) increase. Substitution of alternatives to PVC in cars' undercoating could significantly reduce this chlorine input (Pohle 1997).

There is an increase in contamination before and after shredding cables into PVC fraction and copper fraction. High amounts of PCBs, chlorobenzenes and PAH were found. This contamination is primarily associated with PVC cables: PE cables only contained negligible amounts of the hazardous substances (Kaiser et al. 1993). Because of laws limiting the PCB content of products, this will seriously affect the possibility of re-using PVC cable shredding waste.

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# LEED TSAC PVC Study Database

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### Comment

These comments are submitted because we believe that green buildings should be environmentally healthy buildings that avoid the use of materials that pose unreasonable avoidable risks to public health and environment. We have reviewed the U.S. Green Building Council's LEED Technical and Scientific Advisory Committee (TSAC) report entitled "Assessment of Technical Basis for a PVC-Related Materials Credit in LEED." We are disappointed in the accuracy of some of the scientific information and the overall quality of the scientific analysis in this report. We are concerned that this report will encourage the continued use of polyvinyl chloride (PVC) at a time when many companies have recognized the health and environmental risks that PVC poses and have made the decision to move from using it.

The Center for Health, Environment, and Justice (CHEJ) has closely followed the U.S. Environmental Protection Agency's (USEPA) reassessment of the health effects of dioxin and dioxin-like substances for over 10 years. A significant portion of this work has focused on the role of PVC in the generation of dioxin and dioxin-like substances. We recently completed a report that evaluated the public health and environmental impacts of PVC that primarily focused on what happens at the end of the useful life of PVC materials such as piping, siding, flooring, or windows, when these materials are discarded. This report, entitled "News Comes in 3's - The Poison Plastic, Health Hazards and the Looming Waste Crisis," documents a wide range of severe and long lasting health and environmental hazards directly attributed to the production, use and disposal of PVC products. A copy of our report is attached to these comments. Many of the comments included below are discussed in more detail in our report.

Our main concern with the TSAC Report is that it does not adequately evaluate the public health and environmental risks posed when the useful life of a PVC product ends. Whether a PVC product is burned, whether in an incinerator, backyard burn barrel or during an accidental building vehicle fire, PVC plastic forms dioxins, a highly toxic group of chemicals that build up in the food chain. Dioxins are known to cause cancer, reproductive, developmental and in

problems. Landfilling PVC also poses significant public health and environmental risk to leaching of toxic additives into groundwater, dioxin-forming landfills fires, and emissions in landfill gases.

The TSAC Report also fails to adequately assess the contribution of PVC to dioxin air emissions nationwide. The evidence linking PVC to dioxin air emissions is clearly documented in numerous publications including the USEPA Inventory of Sources of Dioxin in the U.S. These concerns are expressed in more detail below.

For these and other reasons, we feel that the TSAC Report does not accurately reflect current consensus of scientific knowledge of the public health and environmental impacts of PVC. We are concerned that the TSAC Report as written will undermine our efforts and of other organizations to move priority toxic chemicals out of use. We urge the U.S. Building Council to stand with the growing movement of organizations, consumers, and companies who have recognized the lifecycle hazards created by PVC.

Although we have other concerns about the TSAC Report, the thrust of these comments will focus on the committee's failure to adequately evaluate the public health and environmental risks posed when PVC materials are disposed of and the failure to adequately assess the contribution of PVC to dioxin air emissions nationwide.

1) The Life Cycle Assessment (LCA) and Risk Assessment (RA) models used in the TSCA Framework do NOT include a factor to address the environmental and public health risks that result when PVC is disposed of at the end of its useful life as a consumer product (see LCA Framework pp. 22-to 27; RA, pp. 27-31; and Exposure Assessment, pp 32- 37). There is no discussion of the broad environmental and public health risks of PVC in Section 3.3.1 Overview regarding risk assessment estimates (p. 53-58).

This is a major omission. How can a "life-cycle assessment" be complete when it ignores environmental and public health impacts of a major component of a material's life-cycle when it is discarded? PVC waste is primarily disposed of either by burning it in an incinerator or backyard burn barrel, or by placing it in a landfill. When PVC is burned in a municipal or medical waste incinerator, dioxins and other toxic gases are formed, and metals which are present in the waste are released into the air and residual ash. Dioxins are also released when residents in rural areas dispose of their trash by burning it in small furnaces or barrels behind their homes. It is the chlorine in PVC that facilitates the formation of dioxins and other chlorinated organic compounds that are subsequently released into the environment (1).

Waste incinerators are a major source of dioxins released to the air and land. Municipal solid waste incinerators are considered the largest source of dioxin emissions in air. The most recent inventory of dioxin sources in the U.S. estimated that municipal and waste incinerators together account for 55% of all dioxin releases to air (40% and 15% respectively) (2). Dioxin air emissions have since declined as many incinerators have added or improved pollution controls to meet new standards (3, 4). Much of the dioxins formed in waste incinerators are released to the land through landfilling of incinerator ash.

An estimated 250,000 tons of PVC were burned in trash incinerators in the U.S. in 2000. PVC waste contributes substantially to the chlorine content of the waste and to the formation of dioxins in trash incinerator emissions. Estimates of how much PVC waste contributes to the chlorine content in waste streams vary from 35 to 66% (6, 7). Other chlorine sources include food waste and paper. Another source estimates that, on average, about 50 to 67% of the chlorine input in an incinerator can be attributed to PVC (8). However, as much as 80% of the organically bound chlorine, which is thought to be more conducive to dioxin formation than inorganic chlorine, may be from PVC (9).

In addition to dioxins, PVC waste contributes to the formation of hydrochloric acid in the flue gases of incinerators. This gas must be neutralized and removed by scrubbers.

because it damages the air pollution control equipment and requires additional maintenance. In addition, the metal stabilizers in PVC (lead and cadmium) do not break down during incineration but are released either as hazardous air emissions or remain in the ash cinders (7). Older PVC products that used cadmium as a metal stabilizer will contribute cadmium when burned (7). Consequently, burning PVC waste will increase the operating costs of the incinerator (6).

Waste incineration has been linked to a number of serious health problems in plant workers as well as in surrounding communities. Many of these troubles implicate PVC as the major source of contamination. For instance, workers in incinerator plants have increased levels of chlorinated phenols and lead in their body tissues, which may result from PVC, as well as mercury and arsenic (10). The USEPA has reported that metals emissions in incinerators when the chlorine content of the waste rises. In one study, metals were up to seven times higher when the chlorine content of the waste was increased from 0 to 8.3% (11). Elevated chlorine content levels also impair the efficiency of the scrubber to remove metals from stack gases (11). Incinerator operators are not the only exposed group. Populations living near incinerators are particularly vulnerable to elevated levels of dioxins and heavy metals in tissue and blood, as well as to respiratory ailments and cancers (10). Elevated levels of congenital abnormalities have also been observed in newborns in areas in the immediate vicinity of incineration plants (12).

Even distant populations are at risk, as toxic air releases settle on crops and these are transported to other areas and/or eaten by livestock which, in turn, are consumed by people (13, 14). A study by Barry Commoner and researchers at Queens College in New York found Inuit Native peoples living in the northern reaches of Canada, miles from any source of dioxin, had high levels of dioxin in their bodies (15). These researchers also found dioxins released from incinerators and other dioxin sources hundreds of miles away in the U.S. and lower Canada were transported by wind currents to the far reaches of the globe.

Landfilling is the most common disposal option for PVC and thus is a significant part of the disposal stage of the PVC life cycle. The majority of PVC that is discarded as waste ends up in a landfill. However, landfills do not solve the PVC disposal dilemma. They eventually leak, routinely emit toxic gases and occasionally catch on fire.

According to the USEPA, about 1.42 million tons of PVC was present in U.S. municipal solid waste in 2001 (16). This represents less than one percent of the 163 million tons of municipal solid waste disposed of in landfills and incinerators. (This total does not include an additional 49 million tons of municipal discards that were recycled or combusted and contained negligible amounts of PVC.)

The USEPA estimated that about 1.12 million tons of PVC was dumped in landfills in 2001 (16). Using another source of data on municipal waste generation for 2002, the amount dumped in landfills was estimated at 2.04 million tons (5), nearly twice the USEPA amount. This latter estimate assumes the same percent PVC content in the municipal solid waste stream as reported by the USEPA. The estimated number of active landfills in the U.S. could end up ranging from 1,767 (5) to 3,200 (17).

The amount of PVC waste going to landfills is expected to increase substantially over the next 20 years. A study in Europe found the amount of PVC waste generated in the 15 EU member countries will increase from 3.6 million tons per year in 2000 to 4.7 million tons in 2010 and to 6.4 million tons per year by 2020 (18, 19). This is an increase of more than 75% over 20 years. This is because most PVC products were put into commercial use during the 1970's and their useful service life is ending. Components in cars, construction materials and electrical, household and industrial goods typically last from 5 to 15 years (18). Building materials such as pipes, flooring, and siding may last for decades before being replaced (18). As production of these PVC materials has been on going for more than 30 years, the PVC waste that is entering the waste stream today is a reflection of the products put in use years ago. An estimated 150 million tons of PVC will require disposal worldwide in the coming years (20).

PVC is also found in construction and demolition (C&D) waste generated from the construction, renovation, repair and demolition of structures such as residential and commercial buildings, roads, and bridges (21). Franklin Associates estimated that 136 million tons of building-related C&D debris was generated in 1996 (22). The percentage of PVC in C&D waste is hard to estimate. One report specifically identified and estimated percent of vinyl siding and PVC pipes in C&D waste to be 0.63% for the two materials combined (22). Other types of PVC plastic waste were not considered. In 2002, forty-two states reported that 1,931 landfills were dedicated for disposal of C&D waste (5). Most of these landfills are unlined, offering groundwater supplies even less protection from contaminants that may leach from PVC and other C&D waste components.

There are significant dangers associated with the dumping of PVC in landfills. Although there appears to be little degradation of the PVC polymer (19, 23), the additives present in PVC products are not chemically bound to the PVC and they will seep out into the environment over time (6, 23). This is especially true of flexible PVC products. In the case of rigid PVC products, stabilizers are generally thought to be encapsulated in the matrix of the PVC polymer and thus migration is expected to be less than what occurs with the plasticizers (18, 19, 23).

2) The Life Cycle Assessment (LCA) and Risk Assessment (RA) models used in the TSCA do NOT assess the public health and environmental impact of the toxic additives used in the manufacture of PVC products. These additives include stabilizers (lead, cadmium, anti-organotin, and zinc), plasticizers (diethylhexylphthalate (DEHP), Diisononylphthalate (DINP), Diisodecylphthalate (DIDP), and others) that are mixed in with, but are not chemically bound to the PVC.

The most important of these chemical additives are the plasticizers known as phthalate metal stabilizers. Plasticizers are added to PVC to "soften" the plastic and make it suitable for certain applications. About 90% of all phthalates consumed in the U.S. (and about 90% in England) are used in PVC products (8, 24). These plasticizers can make up a large portion in some cases up to 60% by weight, of the vinyl product (25). Because these additives are not chemically bound to the PVC, they will leach out over time (8).

Studies have shown plasticizers such as DEHP and DINP have migrated out of PVC containers used to store food (25, 26); IV bags used to hold blood (27, 28); toys (29, 30); and numerous other products, exposing people to toxic additives (31, 32, 33).

In some cases, these additives will evaporate or "off-gas" from PVC materials like floor wall covering or carpeting, contaminating indoor air (34, 35, 36). A study by the California Air Resources Board measured forty target compounds off-gassing from PVC flooring. Phthalates were found in the air off-gassing from all the vinyl sheets evaluated. tetrahydrofuran, cyclohexanone, toluene and n-tridecane were also found (34). Another study found the degradation of plasticizers from PVC flooring was likely responsible for an increase in adult asthma as well as eye and skin symptoms in workers. The prevalence of these symptoms decreased when the PVC flooring was removed (37). A Swedish study estimated that 42,000 kg of phthalates are released from PVC products worldwide each year (25).

Components of PVC have also been found to leach from PVC pipes. Vinyl chloride has been found to leach from PVC pipes made prior to 1977 (38). PVC pipes made prior to this time had a high residue of vinyl chloride that failed to bond when the vinyl chloride monomer polymerized into polyvinyl chloride. In a study of unplasticized PVC pipe, vinyl chloride was detected in water after 30 days at 2.5 parts per billion (ppb), a level that exceeds the USEPA drinking water standard of 1 ppb (39). Smaller pipe size, longer line length, and higher temperatures all increase the likelihood of vinyl chloride leaching from PVC pipes. Additional studies have found organotin stabilizers also leach from PVC pipes (40, 41, 43).

Phthalates have been shown to cause developmental and reproductive damage (44), alter

liver (45) and kidney function (46) and have been linked to the development of respiratory problems in children (47, 48). More detailed information on the health and environmental impact of phthalates used in PVC products are available from other sources (33, 49, 50).

Metal stabilizers including lead, cadmium, zinc, antimony and the organotin compounds will leach out of PVC products. Lead and cadmium were found to leach out of children's toys made with PVC (51). Lead migrated out of PVC window blinds (52) and into water carried in PVC pipes (53). Lead is a known cause of neurodevelopmental problems (53). Cadmium causes cancer and kidney damage (54).

Organotin stabilizers (tributyltin, tetraethyltin, monooctyltin, dioctyltin) were introduced to replace toxic metal stabilizers like lead and cadmium, but they have also been found to leach from PVC products (32, 40). The organotins affect the central nervous system, liver, immune system and reproductive system (55, 56). The diorganotins are potent developmental toxins (56, 57) and potent teratogens (56, 58). Tributyltin affects the nervous system, and has caused reproductive and developmental problems in animal studies (59, 60).

Antimony trioxide (ATO) is added to PVC used in flexible electrical cables and roofing to inhibit the formation and spread of flames during a fire (61, 62). For flame retardant applications, PVC accounted for 32% of the European market for antimony trioxide in 1995 (61). The antimony, which is a synergist rather than a flame retardant, acts to enhance the flame retarding properties of chlorine in PVC. Antimony trioxide is a suspected human carcinogen when inhaled and is toxic to the lungs, heart, eyes and skin (61, 63). During fires and waste incineration, antimony dust and toxic antimony halides are released. Antimony also catalyzes the formation of dioxins and furans (61).

3) The Life Cycle Assessment (LCA) and Risk Assessment (RA) models used in the TSCA EIS ignore the impact of PVC during accidental fires. This is one of the most important impacts that need to be evaluated in an assessment of the overall life cycle impact of PVC.

In 1995, there were an estimated 574,000 structural fires and another 406,000 vehicle fires in the U.S. (2). When the PVC in buildings and vehicles burns, a variety of toxic substances are formed that pose major public health risks. The primary combustion products are hydrogen chloride gas, carbon dioxide and carbon monoxide (64). Hydrogen chloride gas is a corrosive and highly toxic gas that can burn the skin and cause severe damage to the eyes and lungs. When hydrogen chloride comes in contact with the mucous lining of the lungs, it is converted into hydrochloric acid that can cause severe and permanent respiratory damage (65).

Accidental fires that burn PVC also generate phosgene gas, benzene, toluene, xylenes, dioxins, furans and other products of incomplete combustion (65). The poor combustion conditions that are typical of these fires are ideal for the formation of dioxins and furans (66). Dioxins were found in the air, water, surface soil and nearby vegetation following the burning of a plastics recycling plant in Hamilton, Ontario (67). In the World Trade Center fires, dioxins and furans were identified as significant components of the smoke given off by the smoldering buildings (68). In Germany, dioxin levels in indoor soot remaining after a house fire were found to be as high as 45,000 parts per trillion (ppt) TEQ—more than 100 times the German government's health standard (69). After a fire at a plastics warehouse in Binghamton, NY, dioxin levels in soils were found to be more than 100 times higher than in other areas of the community not impacted by the fire (70).

Firefighters and emergency responders are especially at risk from smoke and gases generated by fires burning PVC. Exposure to combustion gases from building fires has been linked to a high incidence of leukemia and laryngeal and colon cancers in firefighters at young ages (71) and to other adverse health problems including pulmonary hemorrhage and edema due to chemical pneumonitis (72, 73). This is one of the reasons why the International Association of Firefighters supports the use of alternative building materials that do not pose a risk as high as PVC (74).

The toxic gases generated when PVC is burned in accidental fires have resulted in deaths and injuries, including workers exposed to toxic gases from burning electrical wires coated with PVC (75); residents exposed to airborne toxics from a Hamilton, Ontario plastics recycling plant fire (76); and guests who died in the MGM Grand Hotel fire in Las Vegas (77). A summary of the public health hazards associated with accidental fires that burn PVC is published (72).

Accidental fires are unexpected, and thus difficult to regulate, but phasing out PVC would reduce the harm they cause. If PVC was not so widely used as a building material, accidental fires would not produce the toxic combustion products that are specifically caused by burning of PVC. Both immediate and long-term impacts would be lessened: firefighters and victims alike would avoid exposure to the toxic gases and smoke caused by the fire, and leftover ash would be largely free of these toxins as well.

The TSAC Report does acknowledge the serious adverse health effects associated with building fires (Section 3.2.3 PVC fires, pp. 49 to 51). However, the text of the report does not reach any conclusions about the health and environmental risks posed by PVC in accidental fires. In the executive summary of the report, the committee states that "data on PVC fires indicate that with proper protective equipment, firefighters are not at an increased risk for exposure to combustion products from this plastic" (ES, p. 10, line 16). This cavalier statement ignores the fact that some fire fighters and other emergency responders will be exposed if they do not have protective equipment, that members of the public using the building will not be wearing protective equipment, and that people very near the building will be exposed to the toxic fumes generated by the fire and they will not be wearing any protective equipment.

4) The Life Cycle Assessment (LCA) and Risk Assessment (RA) models used in the TSAC report ignore the environmental and public health impact of PVC burned in backyard burn barrels.

The TSAC report does briefly discuss backyard burning (Section 3.2.2, pp. 47 to 49) and the committee does find that "Limited data indicate that backyard burning may be a very significant source of localized dioxin concentrations. Dioxin levels emitted from barrel burning varies significantly with the chlorine content of the fuel source" (ES, p. 10, line 16 to 19). However, the potentially significant impact on public health and the environment that burning PVC in burn barrels poses is not included in the overall environmental and public health assessment conducted in this report.

Backyard burning (also called open burning) generates toxic emissions that are uncontrollable. The smoke and vapors from the open burning of household trash contain many toxic chemicals including dioxins and furans; carbon monoxide; heavy metals such as mercury, lead, arsenic, and cyanide; volatile organic compounds (VOCs) such as benzene, styrene, and formaldehyde; particulates; polycyclic aromatic hydrocarbons (PAHs); and hexachlorobenzene (78, 79). Exposure to these chemicals have been linked to adverse health problems including, but not limited to asthma, lung cancer, and other respiratory ailments, kidney and liver damage, nervous system, reproductive and developmental disorders (80). One study found emissions were highest for VOCs such as benzene and styrene, formaldehyde, hydrogen cyanide and hydrochloric acid, followed by polychlorinated biphenyls (PCBs) and arsenic (79).

Among the toxic byproducts of backyard waste burning, dioxins and furans may pose the greatest public health threat. Dioxins are highly toxic even at low levels and have been linked to serious health problems in people that include cancer and adverse developmental and reproductive effects (80, 81). Dioxins are formed primarily because of low combustion temperatures, poor air distribution, and the presence of chlorine (82). The majority of the chlorine in household trash comes from PVC plastic. Because the emissions from open burning are released close to the ground, they are particularly dangerous to people and animals located nearby. There are also no pollution control devices on these burners.



The backyard burning of household trash also produces residual ash that contains toxic metals such as lead, chromium, mercury and arsenic, as well as PCBs and dioxins (78). The ash left over from the burning is often used by homeowners in gardens or placed in areas where children may play and come in contact with these toxic substances. In gardens, vegetables can absorb and accumulate the metals (78).

5) The Life Cycle Assessment (LCA) and Risk Assessment (RA) models used in the TSCA F ignore the environmental and public health impact of PVC burning in landfill fires.

Landfill fires generate a range of hazardous gases including carbon dioxide, carbon monoxide and hydrogen chloride. Dioxins and furans are also formed (2). Such fires are not uncommon. An average of 8,400 landfill fires are reported each year in the U.S. (84) and their ignition can be traced to a number of causes. Though over half of reported fires have information available as to the initial cause, 40% of reported fires are classified as deliberate or suspicious, 20% are attributable to smoldering waste, and 5% ignite spontaneously. Highly flammable methane gas, released by landfilled waste as it decays, is a primary factor in many cases.

PVC products disposed of in landfills contribute to the formation of dioxins and furans in the event of a fire. Four PVC products—pipes, rigid foils, floorings and cable wires—contribute about 40% of the chlorine content in landfills (23). As previously discussed, chlorine in PVC contributes to the formation of dioxins. Other factors that influence the amount of chlorinated dioxins and furans formed include fire temperature, and the availability of oxygen and catalysts (e.g., copper). Lower oxygen concentrations and temperatures (500-700° C) correspond with elevated dioxin formation (85). Both these conditions occur frequently at landfill fires. Measured concentrations of dioxins and furans in the air of landfill fires are generally high and consistent with evidence gathered from test fires (86).

6) The Life Cycle Assessment (LCA) and Risk Assessment (RA) models used in the TSCA F ignore the contribution of PVC to dioxin air emissions nationwide.

The relationship between PVC and the formation of dioxins in incinerators is a major concern with the disposal of PVC waste material. PVC is a significant chlorine donor in the incineration process, spurring the formation of dioxins. The strongest evidence of this comes from laboratory studies. The German EPA found that burning waste that includes other organochlorines produced dioxins, while burning waste without PVC did not (87). Danish studies found similar results (88, 89). In Japan, researchers found that adding PVC to a mixture of PVC-free material increased dioxin emissions ten fold (90). When added to a mixture of newspapers or to chlorine-free paper and burned, dioxin emissions increased significantly with chlorine and PVC content (91). In a similar study, dioxin levels in fly ash were 200 to 1,200 times higher when PVC was added to a mixture of newspaper or chlorine-free plastics (92). Several other studies found that increased levels in fly ash or unburned residue were correlated with increased PVC levels in the waste stream burned (93, 94, 95).

When elemental chlorine was added to a mixture of coal and salt, dioxin levels were 10 times higher than when the same mixture was burned without the chlorine (96). Adding chlorine gas to chloride-containing vegetable matter resulted in increased dioxin formation (97). In another study, as the level of organochlorines in a waste stream increased, so did the amount of dioxins formed (98). A study in Finland found that burning perchloroethylene in a laboratory produced more dioxins, chlorobenzenes and chlorophenols than burning sodium chloride (99).

There is also evidence from small-scale incinerators that support a relationship between burning organochlorine compounds like PVC and dioxin formation. The Danish EPA found that doubling the PVC content of an incinerator's waste feed increases dioxin emissions by

(100). Conversely, reducing the PVC feed results in a reduction in dioxin emissions. Researchers in Japan found that burning a mixture of PVC and polyethylene produced less amount of dioxins (101, 102). A study conducted for the Dutch Environment Ministry found that PVC levels in the waste stream increased dioxin levels in the air emissions (103). Other studies in both the U.S. (104) and Europe (89, 105, 106, 107, 108, 109) have found a positive correlation between PVC content in a waste stream and dioxin emissions.

An excellent review of the evidence linking chlorine content in the waste stream and emissions has been published (1). This paper identified 47 studies involving laboratory pilot scale combustion system/processes; 12 studies involving small-scale and other combustion systems/processes; and 31 studies involving full-scale combustors that are relevant to the relationship of chlorine content and dioxin emissions. The author found reduced chlorine content was correlated with reduced dioxin formation in all three study groups and concluded that there is "a compelling body of evidence that dioxin formation in waste incinerators decreases when chlorine input is reduced."

The USEPA confirmed that PVC is a dioxin precursor in 1997 (110). They also acknowledged that, "several studies have identified strong correlations between chlorine content and CDD/CDF [dioxin/furan] emissions during combustion tests." As part of their inventory of sources of dioxin, the USEPA has acknowledged that a "review of experimental data clearly indicates an association between chlorine content of feed/fuels and ... synthesis of CDDs/CDFs" (2), though the agency concluded that the overall results "were not unequivocal."

7) The Life Cycle Assessment (LCA) and Risk Assessment (RA) models used in the TSCA Risk Assessment ignore the limitations on the ability to recycle or reuse PVC and its impact on the ability to recycle other plastics.

It is extremely difficult to recycle PVC. The primary reason for this is the lack of uniformity in the composition of PVC products. Vinyl products are made using various formulations that are designed to achieve certain properties and create specific products. To achieve these features, additives such as lead, cadmium and phthalates that enhance certain properties such as durability and plasticity are mixed together with PVC. For example, siding and windows are made with lead to make them more durable, whereas infant chew toys contain phthalates to make them more soft and pliable.

When the different formulations of PVC are mixed together, such as when they are collected as part of a recycling effort, they cannot be readily separated which is necessary to reprocess the PVC back into its original formulation and to retain the unique properties of the original formulation (9, 111). This problem is further complicated because PVC formulations for the same materials have changed over time.

There are other problems with collecting mixtures of PVC for recycling. One difficulty is color. Recycled products must be separated by color, which in most cases is not practical (111). Another difficulty is that soft PVC cannot be used in rigid PVC applications, rigid PVC cannot be used in soft PVC applications since the material has to be reformulated (i.e., new additives need to be added). Thus, when different formulations of PVC are mixed together, it becomes virtually impossible to create a formulation that can be used for any application that requires specific properties.

As a result, a lower quality PVC plastic is produced which cannot be used for the same purpose as the original product (111). Thus, PVC can never be truly recycled into the same quality material. It usually ends up being "downcycled" into lower quality products with less stringent requirements such as speed bumps, parking bumpers, or park benches. When PVC is downcycled, it does not reduce the overall demand for the raw materials (virgin resin) used in making plastic, and has no effect on the amount of vinyl produced each year.

The difficulty in separating PVC from other plastics, such as polyethylene terephthalate (PET) bottles or nylon carpet facing, makes it extremely difficult, if not impossible

recycle those otherwise recyclable materials. PVC also increases the toxic impacts of recycling of other valuable commodities such as copper from wiring and cable used in electronics like computers, steel from the scrapped automobiles and corrugated cardboard containers sealed with PVC tape (113).

For example, PVC severely impacts the recyclability of other plastics such as PET. Bottles made of PET and high density polyethylene (HDPE) make up 95% of all plastic bottles compared to only about 2.3% for PVC bottles (114). PET bottles (recycling code #1) are common and used to contain water, soda, vegetable oil and many other products (114) and are highly recyclable. Lower quality recycled PET (which has greater tolerance for contaminants from PVC) is often used to make a polyester fabric known as "fiberfill" that is used in clothing, sleeping bags, pillows and carpeting. However, higher quality recycled PET (containing little PVC) is increasingly being recycled directly back into bottles. It also has an economic benefit as it is sold for fiber at seven times the price of PET contaminated with PVC (114).

When PVC is mixed together with PET or other highly recyclable plastic, such as in the "bottle" recycling programs favored by the plastics industry, the few PVC bottles that might be collected will be virtually indistinguishable from PET containers due to their similar appearance and density. Sophisticated separation technology that uses optical systems is available to identify and remove unwanted plastic bottles, such as PVC (115). However, the effectiveness of these systems is greatly reduced when the bottles are damaged or dirty. This makes accurate readings difficult to achieve and as a practical matter separating PVC is almost impossible (114, 115).

If the PVC cannot be separated from the PET, it will severely effect the processing of PET bottles into reusable plastic resin. This is because PET and PVC behave very differently when they are processed for recycling. PVC burns at a lower temperature than PET. It melts at the temperature that simply melts PET (114, 116). When this occurs, "black spots" are introduced into the PET resin contaminating the batch and ruining or seriously downgrading the quality of recycled PET residue (114). According to one plastics recycler, "introducing one PET bottle into the recycling process can contaminate 100,000 PET bottles" (114, 116). In addition, when PVC is melted, it generates hydrochloric acid, which will damage the processing equipment (117).

8) The TSCA Report dismisses the environmental and public health impact of PVC production facilities on communities living near these facilities.

After an extensive discussion of ambient exposure data (see pp.79 to 87), the TSCA report concludes that "additional data are needed to determine the potential health risks of individuals living in neighborhoods near vinyl manufacturing facilities" (p. 87). Because the data was limited, the TSCA committee dismissed the impact on surrounding communities.

Scientists always want more data, but that does not mean that these risks should not be estimated and in some way incorporated into the overall assessment of the impact of PVC production facilities on the environment and public health. U.S. communities surrounding vinyl chloride chemical facilities, half of which are in Louisiana, suffer from serious toxic chemical pollution of their groundwater supplies, surface waters and air. Residents of the town of Mossblom, LA had dioxin levels in their blood that were three times higher than normal (118).

In 2000, there were 12 facilities in the U.S. that produced vinyl chloride monomer (VCM) (119). Seven of these plants also produced PVC. As of 2003, there were 24 facilities operated by 12 companies that produced PVC resin in the U.S. (120) and an estimated 25 PVC fabricating facilities (121). These PVC production facilities released 811,000 pounds of VCM and 670,000 pounds of ethylene dichloride (EDC) into the environment in 2002 (122). In addition, 6.5 million pounds of VCM and 2.5 million pounds of EDC were sent off-site to sewage treatment plants or waste treatment facilities (122). It should be noted that

are self-reported numbers that represent an absolute minimum. The actual releases are to be greater.

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# Greening Divisions 15 & 16

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## 1. INTRODUCTION

Significant progress has been made to identify environmentally preferable materials and products for most of the CSI divisions, with the notable exception of Divisions 15 and 16, specifically relating to plumbing and electrical materials. Indeed, a review of BuildingGreen's GreenSpec for Division 15 – *Mechanical* lists nine manufacturers, six representing vitrified clay pipe manufacturers, and three cast-iron soil pipe manufacturers; interestingly, no listings for potable water delivery (supply) are identified. For Division 16, *Electrical*, no manufacturers are listed for wiring, cabling and other electrical materials such as switches. These materials are intimately associated with safety considerations associated with building operations and represent significant cost and volume. Due to the nature of conventional materials used in these applications, they also represent a window of opportunity for market transformation towards substantial improvement relative to environmental health performance over their respective life cycles.

This paper focuses on specific applications of plumbing and electrical materials, code and performance considerations, and a framework to guide the market towards enhanced environmental health performance, with some examples of industry innovators and public policy initiatives.

## 2. CONTEXT

In a 2000 report, *BaselineGreen™ -- GreenBalance™: Balancing Environment and Employment Inputs to the Seattle Justice Center*, co-authored by Center for Maximum Potential Building Systems and Sylvatica, Uniformat Level 2 Building Group Elements were ranked based on upstream environmental burden indicators associated with total air pollution, global warming (CO2 emissions), and toxic releases, with D50, Electrical and D20, Plumbing, ranked in the top eight (out of 11) categories:

Uniformat Level 2 Building Group Elements	Air Pollution	Global Warming	Toxic Releases	Combined Ranking	Final Ranking
C30 Interior Finishes	2	2	1	5	1
B10 Superstructure	1	1	4	6	2
<b>D50 Electrical</b>	<b>4</b>	<b>3</b>	<b>3</b>	<b>10</b>	<b>3</b>
A10 Foundations	4	5	2	11	4
D30 HVAC	7	6	5	18	6
C10 Interior Construction	6	7	6	19	7
<b>D20 Plumbing</b>	<b>8</b>	<b>8</b>	<b>7</b>	<b>23</b>	<b>8</b>

Additionally, several of the U.S. EPA-listed persistent bioaccumulative toxins (PBTs) are associated with electrical and plumbing materials. The U.S. EPA identifies PBT chemicals as of

concern because they are highly toxic, do not break down easily in the environment, and accumulate in living tissues. Among the PBTs linked to Divisions 15 and 16 are: mercury used in electrical switches, lead used as a stabilizer in PVC electrical jacketing and plumbing pipe, cadmium used as a stabilizer in PVC electrical jacketing, and dioxins released as a byproduct of vinyl chloride monomer (VCM) manufacture, a feedstock of PVC, and released as a consequence of accidental or intentional combustion of PVC. Because of the significant and prolonged environmental and human health burdens associated with PBTs, they represent priority chemicals to eliminate as feedstocks or by-products associated with building materials and products, particularly when substitutes of comparable or superior performance are available and competitively priced.

### **3. PLUMBING MATERIALS**

The pipes used to transport potable water (supply) and wastewater (drain, waste and vent) to and from buildings are assumed to be safe, particularly supply pipes carrying drinking water. However, an evaluation of plumbing pipe options and materials associated with their installation distinguishes their respective characteristics, and reveals opportunities to enhance the environmental health profile of these products.

Supply pipes transport potable water from the water source into the building. Copper remains the principal material for this application, with ductile iron, high density polyethylene (HDPE), cross-linked polyethylene (PEX), and polyvinyl chloride (PVC) options. (In the latter case, chlorinated polyvinyl chloride (CPVC) is often used for both hot and cold supply as it can withstand domestic hot water temperatures beyond PVC's tolerances.) For drain, waste and vent (DWV) applications, options are concrete, HDPE, PVC, cast and ductile iron, and vitrified clay.

Using a lifecycle framework, several stages are worth noting. For raw material feedstock, recycled content as a single attribute reveals a range of 100% recycled content for polyethylene drainage pipe and cast and ductile iron, about 64 percent recycled content for copper pipe, and undetermined percentages for PVC pipe. Because recycling processes can be energy-intensive and release toxic chemicals, further analysis is required to determine the relative environmental health burdens and costs associated with recycling the respective materials. Using virgin feedstock, PVC is distinguished as being the only chlorinated compound, representing unique environmental and health exposures including the unavoidable dioxin releases during manufacture of the raw material feedstocks and in the event of combustion.

Installation of the various piping materials is another life cycle stage with clear distinctions. For example, several environmentally-preferred options for joining copper pipe are available. Copper pipe is generally joined using solder and flux; some products are still manufactured with lead. Indeed, as of June 19, 1986, the Safe Drinking Water Act (SDWA), Section 1417(a) states that only "lead free" pipe, solder or flux may be used in the installation and repair of public water systems or any plumbing in residential or non-residential facility providing water for human consumption, connected to the public water system. In the SDWA, "lead free" is defined as solders and flux containing no more than 0.2 percent lead, and pipes, pipe fittings and well pumps containing no more than 8 percent lead. Even small exposures to lead creates hazards to workers during installation and can have long term indoor and outdoor air quality impacts, especially considering lead's persistent and bioaccumulative properties. At least one U.S. manufacturer of 100% lead free solder exists: Tarcorp, Inc. located in Winston-Salem, NC

selling products under the names Taramet Sterling Premium Lead-Free solid wire solder, Sterling Premium Lead-Free water soluble flux, and Dutch Boy Lead-Free solder and flux.

A second option is to use flux formulated to reduce copper corrosion associated with exposure to acidic air and/or water. This is a concern because copper pipe corrosion can release high levels of copper into aquatic ecosystems via wastewater, creating potentially toxic conditions for aquatic species. To retard copper corrosion, an ASTM B813 flux is recommended, and is available through most flux manufacturers.

A third option is avoiding the use of solder and flux altogether. A mechanical joining technique for copper pipe, marketed as ProPress fittings, uses an O-ring gasket and crimping tool for jointing, similar to that used for polyethylene pipe. This method eliminates fumes associated with soldering, and enhances the cleanliness of the pipe, thus significantly limiting the potential toxic exposure to installers. According to the manufacturer, Ridgid, ProPress fittings carry a 50-year warranty against defects, claimed to be equivalent or better than warranties offered on copper tubing sold in the U.S..

Circumventing the need for solder and flux is an inherent attribute of polyethylene pipe, and serves as a principal distinction from PVC pipe which requires a cement to connect pipe lengths. A survey of PVC cements reveal many products have high flammability (3 on the HMIS scale), VOCs greater than 600 g/l (the LEED IEQc4.1 maximum threshold for PVC cement is 510 g/l, based on the South Coast Air Quality Management District standards), and formulations including Tetrahydrofuran. According to OSHA, Tetrahydrofuran has the following health hazards:

*Tetrahydrofuran is a central nervous system depressant in humans; based on effects seen in animals, it may also cause irritation of the mucous membranes and upper respiratory tract and liver and kidney damage. There are no reports of chronic effects in humans [Hathaway, Proctor, Hughes, and Fischman 1991, p. 537]. However, investigators exposed to unknown concentrations while testing tetrahydrofuran's pharmacological properties developed severe occipital headaches [Gosselin 1984, p. II-408]. Researchers engaged in the experimental spinning of synthetic fibers showed a marked decrease in white blood cell count that is believed to have been caused by exposure to tetrahydrofuran, which was used as a solvent; these individuals recovered after 2 years of treatment [HSDB 1989].*

A few PVC cement products are formulated to reduce toxic exposures, including Gorilla PVC cement, which the manufacturer describes as non-toxic, non-flammable, and low odor.

#### **4. ELECTRICAL WIRE & CABLE**

Wire and cable represent a \$20.5 billion industry in the US, with demand for wire and cable used in buildings anticipated to increase by 3.4% per year through 2006. Wire is an individual strand of material of a certain gauge size, or a single conductor, generally made of bare or tinned copper, and covered with insulation. Cable is a product made of two or more wires, covered with an insulated jacket. Halogenated refers to products made with chlorine- or fluorine-based compounds, which emit hydrogen chloride, hydrogen fluoride, and carbon monoxide gases when

burning. Due to fire-related health concerns, there has been a shift in the European market in the public and private sectors towards non-halogenated products, though a similar shift has not occurred in the US market.

According to an industry manufacturer, Jayflex Plasticizer, plasticized PVC is the single largest volume electrical insulating material in current use, with estimates of 55 percent to 60 percent of all wire and cabling manufactured with vinyl. As an insulated jacketing, PVC is noted for its good electrical properties, abrasion and moisture resistance, and potential for custom formulations to meet specific performance requirements. How PVC has historically achieved these performance feats involves the addition of plasticizers and stabilizers (generally heavy metals) that represent concern.

Beginning in September 2003, the State of California, through Proposition 65 legislation, will require cable suppliers to label as hazardous cabling containing lead. PVC is the only plastic material that uses lead as a stabilizer. This legislation is anticipated to be a catalyst for the development of non-lead jacketing products, some of which are beginning to enter the marketplace. The U.S. EPA classifies lead and lead compounds as persistent bioaccumulative toxins, and has reduced thresholds for lead in federal reporting requirements, as have many states, as part of a nationwide initiative to reduce risks to human health and the environment associated with PBT pollutant exposure. To their credit, several PVC cable jacketing manufacturers including Solvay, Gitto-Global Corporation, and AlphaGary Corporation have introduced PVC compounds free of heavy metals; some of these are claimed to come without a pricing premium. However, other concerns about PVC persist including plasticizers used to achieve flexibility, and dioxin releases through the PVC life cycle.

Complicating the lead substitution strategy is the emergence of fluoropolymer jackets (commonly referred to as Teflon® or NEOFロン FEP) as a lead-free alternative to PVC. Frank Bisbee, editor of the cabling industry newsletter Wireville.com, states: "FEP is a long-lasting, highly stable material that contains no lead and no phthalates. From a fire hazard perspective, PVC has a fuel load similar to gasoline, whereas FEP has a fuel load similar to concrete." However, due to health and safety concerns raised about Teflon-based cable, Bisbee and others are withdrawing their endorsement. Cross-linked polyethylene (XLPE) is emerging as a more benign alternative, with Environment Canada reporting its use in the NMD-90 residential building wire niche. In Canada, PVC is used in 60 percent of all wire and cable, polyethylene in 34 percent, and other resins fulfill the balance.

Lead also emerges as a concern associated with the aging of installed wiring and cabling in buildings, especially in light of recent regulations requiring the removal of disconnected products when replaced with upgraded ones as now required by the National Electrical Code's (NEC) 2002 edition. The new code requires the removal of accessible, abandoned cable as a fire safety measure, unless it is identified for future use. This requirement will go a long way to achieve enhanced building health and air quality. But the removal raises concerns about the management of PVC jacketing stabilized with lead and plasticized with phthalates, which has been the prominent voice and data cabling material over the past two decades. According to Frank Peri in *Cabling Business Magazine*, "...there is no cost-effective way to remove lead from the PVC in recycling. ... some environmental studies indicate that the discarded cables disposed of in C and



D (construction and demolition) unlined landfills are leaching toxic substances into the groundwater. The downstream costs for handling HAZMAT may be much higher than current disposal fees.” Mr. Peri also voices concern about the growing awareness of the consequences of PVC jacketing materials disintegrating over time, and the associated release of lead dust that could compromise the building air quality, and notes “...a broad-based, worldwide movement where the goal is to reduce or completely eliminate PVC and these harmful (lead and phthalate) chemicals.”

Low smoke, zero halogenated (LSZH) wire and cable products, principally made of polyethylene and polyolefin, are available in the U.S. for most, if not all, large commercial and industrial wire and cable specifications. Generally, the LSZH are considered more mechanically rugged, and are more expensive, than their halogenated counterparts, though volume discounts may reduce the cost premium. Current U.S. manufacturers include Belden Wire of Richmond, Indiana, Service Wire Co. of Culloden, West Virginia, and Southwire Company of Carrollton, GA. Interestingly, Romex produced an LSZH product but withdrew it from the market due to low demand.

Copper continues to be a dominant wiring material, especially in power applications. Scrap copper represents about 55% of total copper consumed in the US on an annual basis. Because of the performance requirements for high conductivity wiring, the use of recycled copper can introduce trace impurities that negatively impact its qualities. For this reason, copper wiring requires newly mined, or primary copper or scrap copper that has been re-refined, re-smelted and re-refined. The former option – newly mined copper – introduces significant environmental burdens associated with the primary mining and processing of virgin ore.

The Massachusetts Toxics Use Reduction Institute (TURI) based at the University of Massachusetts – Lowell, convened a Wire and Cable Focus Group, *Environmental Challenges in the Coated Wire and Cable Industry*, in June 2001, with approximately 30 representatives from the wire and cable supply chain participating. The purpose of the gathering was to discuss research and technology options to help industry respond to increasingly stringent international environmental, health and safety standards, European initiatives to phase-out PVC and some halogenated flame-retardants, California’s Proposition 65, and increasing focus on lead and PBTs in the United States. Among the recommendations are to: provide information on California’s Proposition 65 requirements and court cases associated with coated wire and cable, especially concerning the ‘safety factors’ for the different chemicals used in these products; assist industry to understand and prioritize relative hazards of different lead compounds and alternatives; assist industry estimate the total cost of using lead, PVC, and brominated flame retardants (BFRs). Currently disposal and OSHA costs are not accounted for when considering alternatives.

## **5. ELECTRICAL SWITCHES & THERMOSTATS**

Approximately 60 percent of mercury releases to the environment are from anthropogenic sources, with 40 percent resulting from naturally occurring phenomena such as volcanoes and wind blown dust. Although the use of mercury in manufactured products is dropping, U.S. EPA estimates about 4 percent of mercury-containing devices in the municipal solid waste stream are thermostats (3.3 percent) and electrical switches (0.77 percent), representing approximately 10

tons per year. (Household batteries are the largest contributor at about 72 percent, with electric bulbs estimated at about 14 percent. While of obvious importance to a mercury elimination strategy, these products are not included in this paper's scope.) Accidental exposure to mercury can result during the maintenance and repair of these devices, when the devices break; in addition, workplace exposure during manufacturing represents an additional risk.

The following chart identifies mercury-containing electrical devices and suggested alternatives:

<b>Mercury-Containing Electrical Device</b>	<b>Estimated Amount of Mercury</b>	<b>Suggested Alternatives</b>
Thermostats	~ 3 grams Hg / tilt switch	Programmable electronic thermostats
Silent Wall Switches	~ 2 grams Hg	Hard-contact wall switches
Temperature Sensitive & Mechanical Tilt Switches	~ 3.5 grams Hg in small electrical switches; industrial switches can contain as much as 8 lbs.	Hard-contact switches, solid-state switches, capacitive sensors, photoelectric sensors, and ultrasonic sensors.
Float Switches	unknown	New float switches are mercury free

## 6. CONCLUSION

Heightened awareness about persistent bioaccumulative toxins and their long-term environmental and health consequences is a catalyst for re-engineering product development to eliminate these worst in class chemicals. Recent policies in the City of Seattle and City of San Francisco have established plans to reduce PBT emissions associated with building material life cycles, while the U.S. EPA and Washington State's Department of Ecology have identified prioritized PBT lists. In the case of Washington State, dioxins, cadmium, lead and mercury, among others, are targeted for virtual elimination from Washington sources. Because of the materials and products used in CSI Divisions 15 and 16, they are prime candidates to come into alignment with these environmental health based policies. Clearly, momentum has begun. A broad and heightened awareness of PBTs in plumbing and electrical equipment can catalyze swift market transformation towards a generation of products that fulfill the environmental and human health considerations consistent with green building objectives.

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### The TSAC Analysis of PVC Fires and Their Impacts

The TSAC report uses only two databases, a medical one and an environmental one. Neither of these databases contains the data and scientific discourse needed to assess the impacts of PVC fires, particularly on health. Such publications as Fire and Materials, Journal of Combustion Toxicology, Fire and Flammability, and a host of governmental reports such as that by the government of Ireland which analyzed the Stardust Disco fire of 1984 (125 people dead) contain absolutely essential data and analyses. The TSAC analysis is an utter travesty because of the ignorance it exposes with respect to the thermochemistry of PVC pyrolysis and combustion, the multifatal fires in which PVC was a major contributor to the atmospheric toxicity, and the role of building design in determining the path and concentration of the products of thermal decomposition at different stages of the fire. These data, statistical analyses, and scientific discussions are widely available and known by those who have even merely put their toes into these waters, so to speak. Failure to include them shows either a willful averting of eyes or a woeful ignorance of the field. Such chemists of the PVC industry itself such as Michael O'Mara published papers showing the mass emission of HCl from PVC at 250°C and the emission of a myriad of organic compounds as the temperature rises toward ignition (600°C). Jeremy Stone wrote the keystone paper on the role of soot - its respirable size and the adsorption of HCl onto its surface-in the lung damage consequent on PVC fires. These papers were published in the 1960's-1970's and would not appear in the databases on which TSAC foolishly relies.

Other relevant publications include Fire Engineering and the journals of the fire service across the country.

The fires that TSAC uses to conclude that PVC is not a special problem in fires were viewed from their outdoor aspects only and were not fires in inhabited buildings. Numerous fires that occurred in various types of inhabited buildings (residences, workplaces, hotels, and places of public assembly such as nightclubs and restaurants) have been described in fire science literature. The enclosing of the space in which the fire occurs prevents the venting of the smoke and keeps the concentrations in the pyrolytic fumes and the smoke high. Furthermore, the design of the building determines where these plumes go and how concentrated they are at the various sites along the pathway. The smoke of the MGM Grand Hotel fire (1980) rose through the elevator shafts and plumbing pipe spaces and concentrated at the top of the building from which it diffused downward. This fire began as a PVC fire in the wire insulation behind a refrigerator display case on the groundfloor; PVC made major contribution to the smoke, as analysis of the metals in the soot from the respiratory tracts of the corpses showed (deposition of Merritt Birky in the litigation; Merritt Birky had been the chemist of the NIST Fire Research Center but later migrated to the National Transportation Safety Board). The design of the building is a crucial factor in the impact of PVC fires (and other fires), and NIST had sponsored much work on modeling fires that included building design among the model parameters. Additionally, reconstruction of many of these fires in hotels, restaurants, stores, and office buildings included a wide range of data such as soot analysis that showed the roles of the various combustible materials. TSAC failed to draw on this rich database. The NFPA does not have (and has never had) competent fire scientists or engineers to reconstruct the mass fatal fires for which it issues reports under contract to FEMA. But insurance companies such as Swiss Reinsurance have done better; Swiss Reinsurance has issued reports over the past 30 years on the role of PVC in mass fatal and very damaging fires in Europe because that company has to pay for rebuilding after the fire and for the liability in the case of injuries and deaths. Factory Mutual, the lab of the US insurance industry, wrote a series of reports on PVC in fires in the late 1970's-early 1980's. Tewarson was the head of that project and published in the fire science literature as well.

Another database of interest is the American Trial Lawyers Associations's computerized listing of suits filed and their outcomes. To gain access, however, one must be a member of the ATLA. That should be no problem for TSAC because they could easily enlist the help of to such a person. PVC has been a major defective product with respect to liability suits. This is not just a matter of prejudice. The suits are rooted in the physicochemical properties of PVC. They range from meatpackers suing because they became asthmatic as a result of sealing PVC wrap to people injured in fires because of the extreme acidity of the smoke.

TSAC ignored many papers in the medical literature on inhalation of PVC smoke. Thorax published the case history of Gerry Bresnan, a firefighter whose lungs were damaged in the NY Telephone Fire because of the extreme acidity of the smoke. Another NY Telephone firefighter came down with cancer of the larynx, and his ENT

specialist also published about the relationship between HCl exposure and laryngeal cancer. The FDNY's magazine Firelines has published at least two descriptions of the NY Telephone Fire (1975) which allude to the particular role of the PVC wire insulation and cable jacketing in the injuries and in the difficulty in controlling that fire (acidity of the smoke, incredible density of the smoke, generation of combustible gases so that secondary fires broke out). Fires such as the NY Telephone Fire have been written up in a variety of publications. They also are described in fire reports written by the chiefs who presided over the fire fight. Since about 1980, FEMA has received standardized fire reports from the major municipalities across the country. This is a rich database and includes listing of the materials and products involved in the fires.

TSAC did not report on all the PVC fires in the databases that they did use. Environmental Science and Technology, Chemosphere, and other environmental publications that should be part of the environmental and medical databases which TSAC says it used have reported on both lab experiments on burning PVC and fire occurrences over the past 30 years. The reports on fire occurrences have included dioxin sampling in the environment of the fire. For example: a paper reporting on the elevated dioxin body burden of rodents near a large PVC fire site (in comparison with rodents farther from the site) appeared in the Medline database but was never mentioned in the TSAC analysis. The lab experiments have reported on dioxin generation from burning PVC under various conditions. In the medical literature are famous papers such as that by Dyer and Esch (1976, JAMA) about firefighters and others who were exposed to smoke from burning PVC. There is a huge occupational health literature on such topics as polymer fume fever which was first discovered in Teflon factory workers but was found to occur in PVC factory workers as well. This is a flu-like illness from inhaling fumes from heated resin; it sometimes progresses to pulmonary fibrosis/emphysema because the acid destroys the elastic collagen in the lung. Indeed, large numbers of papers reporting on vinyl chloride monomer exposure in PVC factories and health consequences, on effects of PVC particles on lung function of PVC factory workers, and exposure to fumes from PVC are listed in Medline, but not part of the TSAC discussion or the Life Cycle Analysis.

Finally, in its discussion of the papers that it did acknowledge finding, the TSCA team showed bias in attributing credibility. The Markowitz papers were dismissed out of hand without foundation. Yet, the physical and mental sequelae described by Markowitz are entirely consistent with both the chemistry of PVC fumes and smoke and with the previous publications in the medical literature on PVC smoke exposure (literature ignored by TSCA).

In summary: TSCA ignored most of the data and scientific discussion that has been published on PVC combustion chemistry and on the health impacts of fires fueled by PVC over the past 30 years. Labeling PVC a green building material would be a gross travesty that would discredit the entire process of certification. It would totally omit the basic physicochemical properties of PVC which are especially dangerous in fires and problematic for such environmentally important issues as re-use, recycling, and durability under the expected range of environmental factors

(temperature, humidity, air pollution, UV light, physical stresses such as shaking and torsion). The vast literature of polymer physics and chemistry was never part of this so-called analysis. A basic understanding of what PVC is and how it behaves when confronted with common physical and chemical environmental factors must underlie any sound, accurate, and verifiable model of the PVC Life Cycle.

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A new article by respected environmental journalist Marla Cone lays bare the question of whether the or not the real consequences of human chemical exposures are valued by the US green building movement as it debates a PVC-related materials credit for the US Green Building Council's LEED green building rating system. Cone's latest report, *Dozens of Words for Snow, None for Pollution*, is an eyewitness rendering of life at ground zero of toxic pollution, the Circumpolar Arctic, which she dubs "the planet's chemical trash can, the final destination for toxic waste that originates thousands of miles away". She's talking about chemicals such as POPs, Persistent Organic Pollutants. To understand how natural forces conspire to carry the most toxic industrial pollutants northward to the earth's most pristine environment, recall the ozone hole, then factor in migrating, contaminated wildlife. The Stockholm Convention on Persistent Organic Pollutants sets a goal of elimination for 12 of these chemicals. Four of them are unintentional byproducts of the PVC lifecycle: hexachlorobenzene, dioxins, furans, and PCBs, as is mercury, a by-product of some chlorine facilities. Cone documents PCBs and mercury in babies' cord blood and mothers' milk in the Arctic at 50 times higher than in urban areas of the United States and Europe, affecting between 60% to 95% of women and children in various communities, and having measurable impacts on the babies including, lower birth weight, impaired memory skills and difficulty in processing new information. Earlier studies have found that dioxin concentrations in Inuit mothers' milk are twice the levels observed in southern Quebec. The hard truth Cone reveals is that 650,000 native people of the


circumpolar North are literally forced to pick their poison: the chemicals, bioaccumulated in the fatty meat of the marine mammals and seafood the Inuit eat as a matter of culture and routine, or the expensive sugars, carbs and fat in the rations shipped to their convenience stores from outside. Canadian authorities agree with the Aboriginal leaders - the traditional diet is the most affordable, plentiful, and otherwise healthy food for them. But the people are anxious, anxious like most of us never know, anxious in the way you get when you're not sure whether you are feeding your child something poisonous.

None of this human suffering, none of the PCBs and none of the mercury, appear to register among the data fields, formulas and models that USGBC is currently using to evaluate what it calls hypothetical receptors and pathways for exposure contaminants associated with building products. Which raises the question: What scientific ethic, what green building principle, what institutional value at the USGBC, is elevated by this decision to ignore evidence of an infant receptor, if you will, of PCBs, Mercury and Dioxin via the pathway, if you wish to call it that, of the womb and mother's milk?

We stopped using asbestos when we found it was killing people. We didn't perform life cycle assessments to determine if it was a better product than the alternatives. We stopped using it. If PVC cannot be used for windows in LEED projects, then window manufacturers will find another plastic to build windows out of and market transformation will begin. LEED must LEAD!!

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## FFs Express Concern Over NY Governor Pataki's Veto of Ban on PVC Pipe

December 21, 2004 - Fire fighters and a coalition of environmental groups are protesting New York Governor George Pataki's veto of a bill that would have extended a New York state ban on polyvinyl chloride (PVC) pipe used in large residential construction. "This veto is a major setback to protecting fire fighters from toxic chemical exposure," says IAFF General President Harold Schaitberger. "It should never have been vetoed."

PVC pipe poses dangerous health hazards in its manufacture, product life and disposal. Fire fighters, along with plumbers and other environmental groups, are concerned about the dangers of plastic piping when burned in building fires or in incinerators. Still, opponents of the plastic pipe ban consider it no more hazardous than other plastic building materials.

While the two sides disagree about the safety of the plastic piping, Pataki says his veto was based on serious technical defects that would have hindered compliance and enforcement efforts. Yet the governor approved the ban three years ago over the objections of construction, development and the plastics industries that maintained that the legislation would add significantly to the cost of new buildings.

"The governor had a golden opportunity to protect New Yorkers from exposure to this poison plastic," says IAFF 1st District Vice President Kevin Gallagher. "In vetoing this legislation, he has put the health and safety of fire fighters and residents across the state of New York at risk."

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## Organization Chart

### IAFF Headquarters

#### GENERAL PRESIDENT

Harold A. Schaitberger  
*General President*

Michael J. Crouse  
*Chief of Staff to the General President*

#### GENERAL SECRETARY-TREASURER

Vincent J. Bollon  
*General Secretary-Treasurer*

Erick Genser  
*Administrative Assistant to the General Secretary-Treasurer*

#### CANADIAN OFFICE

Jim Lee  
*Assistant to the General President for Canadian Operations*

#### COMMUNICATIONS AND MEDIA

Jeff Zack  
*Assistant to the General President for Communications and Media*

#### Communications

Jane Blume  
*Director of Communications*

#### EDUCATION, HAZMAT, WMD AND TRAINING

Dave Neun  
*Acting Assistant to the General President for Education and Training*

#### HazMat

Elizabeth Harman  
*Director of HazMat Training*

#### Weapons of Mass Destruction

Vacant

#### GOVERNMENTAL AND PUBLIC AFFAIRS

Kevin O'Connor  
*Assistant to the General President for Governmental and Public Affairs*

#### Governmental Affairs

Barry Kasinitz

#### TECHNICAL ASSISTANCE AND INFORMATION RESOURCES

Lori Moore  
*Assistant to the General President for Technical Assistance and Information Resources*

#### Fire and EMS Operations/GIS

Jonathan Moore  
*Director of Fire and EMS Operations/GIS*

#### Labor Issues and Collective Bargaining

Michele Shaffer  
*Director of Labor Issues and Collective Bargaining*

#### GENERAL COUNSEL

Kurt Rumsfeld  
*IAFF General Counsel*

#### BUDGET AND FINANCE

Don Copley  
*Assistant to the General Secretary-Treasurer for Budget and Finance*

#### Budget and Finance

Kristin Gifford  
*Director of Budget and Finance*

#### HUMAN RESOURCES/GENERAL ADMINISTRATION

Kenneth Long  
*Human Resources/General Administration  
Assistant to the General Secretary-Treasurer*

#### IT OPERATIONS AND SUPPORT

Eric Lamar

*Director of Governmental/Legislative Affairs*

*Assistant to the General President*

**Political Action**

David Billy  
*Director of Political Action*

David Bernard

*Assistant to the General President for IT  
Operations and Support*

**HEALTH, SAFETY AND MEDICINE**

Rich Duffy  
*Assistant to the General President for Health,  
Safety and Medicine*

**IT Operations and Support**

Carmen Gloukhoff  
*Director of IT Operations and Support*

**Health and Safety**

Patrick Morrison  
*Director of Health and Safety*

**Web Operations**

Bentley Westfield  
*Director of Web Operations*

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Secretary-Treasurer

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Grant Recipients

Medical Advisors





**CODE OF ORDINANCES  
City of  
NACOGDOCHES, TEXAS**

**Codified through  
Ord. No. 1392-11-05, enacted Nov. 15, 2005.  
(Supplement No. 12, Rev.)**

**Preliminaries**

**CODE OF ORDINANCES  
CITY OF  
NACOGDOCHES, TEXAS**

\_\_\_\_\_  
Adopted, April 17, 2001

Effective, May 1, 2001

\_\_\_\_\_  
Published by Order of the City Commission

\_\_\_\_\_  
Published by Municipal Code Corporation  
Tallahassee, Florida 2001

**OFFICIALS**

of the

**CITY OF**

**NACOGDOCHES, TEXAS**

**AT THE TIME OF THIS CODIFICATION**

\_\_\_\_\_  
Richard D. Johnson  
*Mayor/Chair of the Commission*

\_\_\_\_\_  
Don Alexander  
Mary Cartwright  
Billy Huddleston, Jr.  
Linda B. McKinney  
*City Commission*

**DIVISION 1. GENERALLY****Sec. 14-236. Adoption of code.**

The International Plumbing Code, 2000 edition with its amendments and appendixes are hereby adopted as the plumbing code for the city, except for such exceptions and additions as are set forth in this article.

(Code 1971, § 22-1; Ord. No. 1265-9-01, 9-4-2001)

**State law references:** Adoption of plumbing standards, Vernon's Ann. Civ. St. art. 6243-101, § 5B.

**Sec. 14-237. Amendments to plumbing code.**

The plumbing code adopted in section 14-236 is amended as follows:

*Section 105, Permits* is amended by adding the following subsections:

*105.3 Permits required.*

(a) It shall be unlawful to construct, install or cause to be installed any plumbing as defined herein without securing a plumbing permit from the City of Nacogdoches in the amount of \$25.00, therefore except as otherwise provided for in paragraph 105.4.

(b) It shall be unlawful for any person to make any extension to any lines or pipes, using water from city water mains, whether within or without the corporate limits of the city, or to add any pipes or to change any pipes or lines from a water line, apartment, house, premises, or meter without first securing a permit for such changes except as otherwise provided in paragraph 105.4.

(c) Permits shall be required for the replacement of water heaters.

*105.4 Permits not required.*

No plumbing permit is required to do minor repairs such as the maintenance, repair or replacement in kind of the following:

- (a) Yard hydrants and sillcocks;
- (b) Flush valves and float-balls in water closet tanks;
- (c) Accessible traps on lavatories or sinks;
- (d) Replacing of plumbing fixtures where no change on "roughing-in" is involved except replacement of water heaters. (See subparagraph 105.3(c).)

The above examples are representative only and should not be considered as a limitation on the term "minor repairs."

*105.5 Issuance of permit.*

The plumbing inspector or his designated representative shall issue all plumbing permits in accordance with the provisions and requirements of this code. All applications for permits shall give the correct location of the building, name of the owner of such building, and a complete statement of the work and fixtures to be installed. The plumbing inspector may require a complete plan of the work to be performed if considered necessary.

*105.6 Special permits authorized.*

A special permit may be issued, in writing, by the plumbing inspector when plumbing cannot be installed in accordance with all of the provisions of this code, if in his judgment the conditions

require it. Application for this type permit shall be made in writing accompanied by a sketch showing the work to be done. Said sketch must be kept on file in the plumbing inspector's office. In other work pertaining to but not specifically covered by this code, the plumbing inspector may prescribe such specifications as may be necessary and shall be consulted before any work is started.

*105.7 Persons who may obtain a permit.*

Permits shall be issued only to the following:

- (a) Any master plumber licensed by the state board of plumbing examiners.
- (b) Any property owner for plumbing work to be done by him in a building owned or occupied by him as his home.
- (c) Any appliance dealer or employee of an appliance dealer who is acting as an appliance installation man or appliance service man in connecting appliances to existing piping installations.

*105.8 Permits not transferable.*

Each permit issued under this code shall be personal to the permittee. No such permit shall be assigned or transferred to another person, and no person shall permit another person to obtain a permit in his name or permit any plumbing or gasfitting work to be performed under his permit by any person other than a person authorized to do the same. If there is any doubt as to whether or not a person is authorized to do such plumbing work for the permittee, evidence of cancelled payroll check may be required.

*105.9 False statement or bad faith.*

Any person who shall willfully make a false statement in order to obtain a permit shall be guilty of a misdemeanor and subject to the penalty herein. Bad faith or unreasonable delay in the performance of plumbing work shall be deemed a sufficient reason for subjecting the plumber so offending to a suspension of the permit, and no further permit shall be issued until such act of bad faith or unreasonable delay has been corrected.

*Section 705.2 Large pipes* is amended to read as follows:

- (a) For building sewers six inches and larger, manholes shall be provided and located at each change in direction and at intervals of not more than 500 feet.
- (b) Building drains six inches and larger shall be provided with full size cleanouts.

*Section 1210.1 Materials* is amended to read as follows:

- (a) Aboveground materials for water-distribution pipes and tubing shall be brass, copper water tube minimum grade "H," cast iron pressure pipe, galvanized steel, except that changes in direction in copper tube (ASTM B88) may be made with bends having a radius of not less than four diameters of the tube, providing that such bends are made by use of forming equipment which does not deform or create a loss in cross sectional area of the tube.
- (b) Underground, inaccessible water distribution piping under slab shall be copper water minimum type "M," brass, cast iron pressure pipe or galvanized steel pipe, all to be installed with approved fittings or bends. Any material subject to corrosion shall be protected when used in concrete or corrosive soil.

*Section 1302* is amended by adding the following subsection:

*1302.6 Depth of building sewer.*

Building sewer must be installed with minimum of 12 inches of cover. Where conditions prohibit the required amount of cover, cast iron soil pipe with caulked or approved mechanical joints must be used.

*Appendix H(a), Permit fees* is amended to provide that the permit fees are on file in the city secretary's office.

(Code 1971, § 22-3; Ord. No. 1388-9-05, 10-1-2005)

Code Ark. R. 007 24 016

007 24 CARR 016

CODE OF ARKANSAS RULES  
007. DEPARTMENT OF HEALTH  
24. DIVISION OF PROTECTIVE HEALTH CODES  
016. RULES AND REGULATIONS PERTAINING TO CHLORINATED POLYVINYL CHLORIDE  
(CPVC) PIPE AND FITTINGS FOR HOT AND COLD WATER DISTRIBUTION SYSTEMS

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Current through May 2006 (Issue 71)

007 24 016. Rules and Regulations Pertaining to Chlorinated Polyvinyl Chloride (CPVC) Pipe and Fittings for Hot and Cold Water Distribution Systems

RULES AND REGULATIONS PERTAINING TO

Chlorinated Polyvinyl Chloride (CPVC) Pipe and Fittings for Hot and Cold Water  
Distribution Systems

SECTION I. Authority

The following regulation is duly adopted and promulgated by the Arkansas State Board of Health pursuant to the authority expressly conferred by the laws of the State of Arkansas in Act 200 of 1951, as amended, and Act 96 of 1913, as amended.

SECTION II. Purpose

To amend chapter 10, Sections 10.1.3-10.1.4-10.1.5 and chapter 3, of the Arkansas State Plumbing Code and establish standards for potable hot and cold water distribution systems using chlorinated polyvinyl chloride SDR11 (CPVC) pipe and fittings intended for installation in residential buildings, including all components supplied or specified by the manufacturer.

SECTION III. Definitions

Approved -- Acceptable to the provisions of this code or the authority having jurisdiction.

Authority Having Jurisdiction -- In this chapter, the administration authority or authority having jurisdiction is the state of Arkansas that administers or enforces the provisions of this chapter as adopted or amended.

C.P.V.C. Pipe -- Chlorinated Polyvinyl Chloride SDR11 (CPVC) pipe and fittings shall meet ASTM D2846; ASTM F441; ASTM F442; and NSF Standards 14 and 61. SDR11 Copper tube size CPVC shall carry a pressure/temperature rating of not less than 160 psi at 73.4° F, 100 psi at 180° F.

Corrosive Water -- Means potable water with pH levels below 7.0 or water whose physical and chemical properties cause it to dissolve pipe, fixtures, and accessories thereby shortening their ordinary life or causing the water to violate drinking water standards.

Plate or Board Support -- A plate or wood backing that is nailed or screwed to the stud or studs to provide a rigid support for the pipe or tubing.

Potable Water -- Potable water is water that is satisfactory for drinking, culinary and domestic purposes, and meets the requirements of the State Department of Health.

Residential Building -- Means a dwelling place for one who makes their home in a particular place that is four (4) units or less whether under a single roof or separate buildings and share common property boundaries.

Solvent Cements -- Solvent Cements for use with Chlorinated Polyvinyl Chloride (CPVC) shall meet ASTM F493, ASTM D2846 and NSF Standard 14.

State Administrative Authority -- Means the State Health Officer or his/her designee that administers and

enforces the provisions of the State Plumbing Code as adopted or amended.

**Water Service Pipe** -- The water service pipe is the pipe from the water main or other source of water supply to the building served.

**Water System** -- The water supply system of a building or premises consists of the water service pipe, the water distributing pipes and the necessary connecting pipes, fittings, control valves and all appurtenances in or adjacent to building or premises.

#### SECTION IV. Restrictions

CPVC water pipe shall not be installed within 6" of any gas appliance vents or within 12" of any recessed light fixtures.

This regulation does not allow (CPVC) to be installed for temperature & pressure relief line discharge on water heaters.

CPVC is approved for above concrete installation only. However, CPVC may be installed under the slab or concrete of a residential building plumbing system when the State Administrative Authority has determined that corrosive water will have an adverse effect on metallic piping. It shall be the responsibility of the person (s) requesting to use CPVC to provide proof that the public or private water source supplying the plumbing system is corrosive before the State Administrative Authority can approve CPVC pipe for underslab installation.

This regulation applies to residential living units having four (4) units or less whether under a single roof or separate buildings and share common property boundaries. CPVC water pipe is expressly prohibited in commercial buildings.

#### SECTION V. Materials

Piping systems components shall be constructed entirely of new and unused parts and materials.

Piping systems components and materials shall have been evaluated and found to be suitable for their intended usage by a testing agency recognized by the authority having jurisdiction.

When requested, the manufacturer shall furnish evidence acceptable to the authority having jurisdiction concerning the composition of the materials used in all components of the piping system.

The construction of parts not specifically covered by this regulation shall be in accordance with reasonable concepts of safety, substantially and durability.

Cutting and joining of tubing shall be done in compliance with the manufacturer's recommendation.

#### SECTION VI. Instructions and Requirements for Installation

The manufacturer shall provide complete detailed instructions, including appropriate illustrations, necessary for proper installation and use of the piping system. Included in the instructions shall be statements to the effect that:

Piping systems components shall be constructed entirely of new and unused parts and materials.

The installation must be in accordance with the manufacturer's recommendations and the applicable state/local plumbing codes and regulations.

Precautions must be taken by the installer to ensure any exposed tubing is not damaged or abused during building construction or reconstruction by using approved protectors.

Only the components provided or specified by the manufacturer as part of the piping system are to be used in the installation.

Installation clearance holes for routing the tubing through studs, joists, plates, etc., shall have a diameter 1/2 1/2 inch greater than the outside diameter of the tubing.

Each branch run of tubing intended to serve plumbing fixtures and equipment shall be securely fastened in place and included as part of the pressure test.

Horizontal runs shall be supported with a minimum distance of 36".

Vertical runs shall be supported with a minimum distance of 5'.

Provisions shall be made to allow adequate clearance between tubing and the structure (bores holes or sleeves) to allow freedom of movement due to thermal expansion and contraction.

#### SECTION VII. Working Pressure

This regulation applies to piping system for use with potable water system with pressure/ temperature ratings of not less than 160 psi at 73.4 ° F, 100 psi at 180° F.

#### SECTION VIII. Marking Requirements

Each component of a piping system (tubing and fitting and manifold shall bear a permanent marking of the following):

Manufacturer's name, trade-mark Symbol of the organization making the test for compliance with the regulation B.

Tubing shall bear a permanent marking of the following:

All (CPVC) tubing shall be marked with its appropriate classification as described in the definitions Section III. ASTM & SDR number.

Temperature & pressure rating.

The words potable or initials NSF-PW.

The markings specified in Section VIII paragraphs A and B shall appear on the tubing at not more than 5' intervals.

#### SECTION IX. Severability

If any provision of these regulations, or the application thereof to any person is held invalid, such invalidity shall not affect other provisions or application of these regulations which can give effect without the invalid provisions or applications, and to this end the provisions hereto are declared to be severable.

#### SECTION X. Repeal

All regulations and parts of regulations in conflict with this regulation are hereby repealed.

<General Materials (GM) - References, Annotations, or Tables>

AR ADC 007 24 016

END OF DOCUMENT

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Proposed Int. No. 478-A

By Council Members Provenzano, Lopez, Oddo, Comrie, Sanders Jr., Katz, Rivera, Lanza, Weprin, Vallone Jr., Felder, Sears, Gallagher, Jennings, Reed, Stewart, Avella, Foster and Brewer (by request of the Mayor)

A LOCAL LAW

To amend the administrative code of the city of New York, in relation to enacting the New York city plumbing code based on the 2003 edition of the International Plumbing Code published by the International Code Council and enacting administrative provisions applicable to such New York city plumbing code and to such other codes as may hereafter be enacted by the city based on the 2003 editions of the International Building Code, the International Fuel Gas Code, the International Mechanical Code, and the International Residential Code.

Be it enacted by the Council as follows:

Section 1. The administrative code of the city of New York is amended by adding a new title 28 to read as follows:

TITLE 28  
NEW YORK CITY CONSTRUCTION CODES

CHAPTER 1  
ADMINISTRATION AND ENFORCEMENT

SECTION 101  
GENERAL

§28-101.1 Title. The provisions of this chapter shall apply to the administration and enforcement of the codes to be enacted and set forth in this title. The codes to be enacted and set forth in this title shall be known and may be cited as the “New York city construction codes” and shall consist of:

The New York city plumbing code.

The New York city building code.

The New York city mechanical code.

The New York city fuel gas code.

The New York city residential code.

§28-101.2 Intent. The purpose of this code is to provide reasonable minimum requirements and standards, based upon current scientific and engineering knowledge, experience and techniques, and the utilization of modern machinery, equipment, materials, and forms and methods of construction, for the regulation of

substitute for the balanced pressure, thermostatic or combination shower valves required in Section 424.3.

**SECTION PC 605**  
**MATERIALS, JOINTS AND CONNECTIONS**

**605.1 Soil and ground water.** The installation of a water service or water distribution pipe shall be prohibited in soil and groundwater contaminated with solvents, fuels, organic compounds or other detrimental materials causing permeation, corrosion, degradation or structural failure of the piping material. Where detrimental conditions are suspected, a chemical analysis of the soil and ground water conditions shall be required to ascertain the acceptability of the water service or water distribution piping material for the specific installation. Where detrimental conditions exist, approved alternative materials or routing shall be required.

**605.2 Reserved.**

**605.3 Water service pipe.** Water service pipe shall conform to NSF 61 and shall conform to one of the standards listed in Table 605.3. All ductile iron water pipe shall be cement mortar lined in accordance with AWWA C104.

**605.3.1 Dual check-valve-type backflow preventer.** Where a dual check-valve backflow preventer is installed on the water supply system, it shall comply with ASSE 1024.

**TABLE 605.3**  
**WATER SERVICE PIPE**

<b><u>MATERIAL</u></b>	<b><u>STANDARD</u></b>
Brass pipe	ASTM B 43
Copper or copper-alloy pipe	ASTM B 42; ASTM B 302
Copper or copper-alloy tubing (Type K)	ASTM B 75; ASTM B 88; ASTM B 251; ASTM B 447
Ductile iron water pipe	AWWA C151; AWWA C115
Stainless steel pipe (Type 304/304L)	ASTM A 312; ASTM A 778
Stainless steel pipe (Type 316/316L)	ASTM A 312; ASTM A 778

**605.4 Water distribution pipe.** Water distribution pipe shall conform to NSF 61 and shall conform to one of the standards listed in Table 605.4.

**TABLE 605.4**  
**WATER DISTRIBUTION PIPE**

<b><u>MATERIAL</u></b>	<b><u>STANDARD</u></b>
Brass pipe	ASTM B 43



Copper or copper-alloy pipe	ASTM B 42; ASTM B 302
Copper or copper-alloy tubing (Type K, L)	ASTM B 75; ASTM B 88; ASTM B 251; ASTM B 447
Stainless steel pipe (Type 304/304L)	ASTM A 312; ASTM A 778
Stainless steel pipe (Type 316/316L)	ASTM A 312; ASTM A 778

**605.5 Fittings.** Pipe fittings shall be approved for installation with the piping material installed and shall conform to the respective pipe standards or one of the standards listed in Table 605.5. All pipe fittings utilized in water supply systems shall also conform to NSF 61. The fittings shall not have ledges, shoulders or reductions capable of retarding or obstructing flow in the piping. Ductile and gray iron pipe fittings shall be cement mortar lined in accordance with AWWA C104.

**605.5.1 Mechanically formed tee fittings.** Mechanically extracted outlets shall have a height not less than three times the thickness of the branch tube wall.

**605.5.1.1 Full flow assurance.** Branch tubes shall not restrict the flow in the run tube. A dimple/depth stop shall be formed in the branch tube to ensure that penetration into the collar is of the correct depth. For inspection purposes, a second dimple shall be placed 0.25 inch (6.4 mm) above the first dimple. Dimples shall be aligned with the tube run.

**605.5.1.2 Brazed joints.** Mechanically formed tee fittings shall be brazed in accordance with Section 605.14.1.

**TABLE 605.5  
PIPE FITTINGS**

<b>MATERIAL</b>	<b>STANDARD</b>
Cast-iron	ASME B16.4; ASME B16.12
Copper or copper alloy	ASME B16.15; ASME B16.18; ASME B16.22; ASME B16.23; ASME B16.26; ASME B16.29
Gray iron and ductile iron	AWWA C 110; AWWA C 153
Stainless steel (Type 304/304L)	ASTM A 312; ASTM A 778
Stainless steel (Type 316/316L)	ASTM A 312; ASTM A 778
Steel	ASME B16.9; ASME B16.11; ASME B16.28

**605.6 Flexible water connectors.** Flexible water connectors exposed to continuous pressure shall conform to IAPMO PS 74 95 and PS 48 92, shall not exceed 24 inches (610 mm), shall be used in exposed locations only and shall be used singularly, that is, two connectors can not be joined.

**605.7 Valves.** All valves shall be of the approved type and compatible with the type of piping material

installed in the system.

**605.8 Manufactured pipe nipples.** Manufactured pipe nipples shall conform to the standard listed in Table 605.8.

**TABLE 605.8**  
**MANUFACTURED PIPE NIPPLES**

<u>MATERIAL</u>	<u>STANDARD</u>
<u>Brass-, copper-, chromium-plated</u>	<u>ASTM B 687</u>

**605.9 Prohibited joints and connections.** The following types of joints and connections shall be prohibited:

1. Cement or concrete joints.
2. Joints made with fittings not approved for the specific installation.
3. Solvent-cement joints between different types of plastic pipe.
4. Saddle-type fittings.

**605.10 and 605.11 Reserved.**

**605.12 Brass.** Joints between brass pipe or fittings shall comply with Sections 605.12.1 through 605.12.3.

**605.12.1 Brazed joints.** All joint surfaces shall be cleaned. An approved flux shall be applied where required. The joint shall be brazed with a filler metal conforming to AWSA5.8.

**605.12.2 Mechanical joints.** Mechanical joints shall be installed in accordance with the manufacturer's instructions.

**605.12.3 Threaded joints.** Threads shall conform to ASME B1.20.1. Pipe-joint compound or tape shall be applied on the male threads only.

**605.13 Gray iron and ductile iron joints.** Joints for gray and ductile iron pipe and fittings shall comply with AWWA C111 and shall be installed in accordance with the manufacturer's installation instructions.

**605.14 Copper pipe.** Joints between copper or copper-alloy pipe or fittings shall comply with Sections 605.14.1 through 605.14.4.

**605.14.1 Brazed joints.** All joint surfaces shall be cleaned. An approved flux shall be applied where required. The joint shall be brazed with a filler metal conforming to AWS A5.8.

**605.14.2 Mechanical joints.** Mechanical joints shall be installed in accordance with the manufacturer's instructions.

**605.14.3 Soldered joints.** Solder joints shall be made in accordance with the methods of ASTM B 828. All cut tube ends shall be reamed to the full inside diameter of the tube end. All joint surfaces shall be cleaned. A flux conforming to ASTM B 813 shall be applied. The joint shall be soldered with a solder conforming to ASTM B 32. The joining of water supply piping shall be made with lead-free solder and fluxes. "Lead free" shall mean a chemical composition equal to or less than 0.2-percent lead.

**605.14.4 Threaded joints.** Threads shall conform to ASME B1.20.1. Pipe-joint compound or tape shall be applied on the male threads only.

**605.15 Copper tubing.** Joints between copper or copper-alloy tubing or fittings shall comply with Sections 605.15.1 through 605.15.4.

**605.15.1 Brazed joints.** All joint surfaces shall be cleaned. An approved flux shall be applied where required. The joint shall be brazed with a filler metal conforming to AWS A5.8.

**605.15.2 Flared joints.** Flared joints for water pipe shall be made by a tool designed for that operation.

**605.15.3 Mechanical joints.** Mechanical joints shall be installed in accordance with the manufacturer's instructions.

**605.15.4 Soldered joints.** Solder joints shall be made in accordance with the methods of ASTM B 828. All cut tube ends shall be reamed to the full inside diameter of the tube end. All joint surfaces shall be cleaned. A flux conforming to ASTM B 813 shall be applied. The joint shall be soldered with a solder conforming to ASTM B 32. The joining of water supply piping shall be made with lead-free solders and fluxes. "Lead free" shall mean a chemical composition equal to or less than 0.2-percent lead.

**605.16 through 605.21 Reserved.**

**605.22 Stainless steel.** Joints between stainless steel pipe and fittings shall comply with Sections 605.22.1 and 605.22.2.

**605.22.1 Mechanical joints.** Mechanical joints shall be installed in accordance with the manufacturer's instructions.

**605.22.2 Welded joints.** All joint surfaces shall be cleaned. The joint shall be welded autogenously or with an approved filler metal as referenced in ASTM A 312.

**605.23 Joints between different materials.** Joints between different piping materials shall be made with a mechanical joint of the compression or mechanical-sealing type, or as permitted in Sections 605.23.1 and 605.23.3. Connectors or adapters shall have an elastomeric seal conforming to ASTM D 1869 or ASTM F 477. Joints shall be installed in accordance with the manufacturer's instructions.

**605.23.1 Copper or copper-alloy tubing to galvanized steel pipe.** Joints between copper or copper-alloy tubing and galvanized steel pipe shall be made with a brass fitting or dielectric fitting. The copper tubing shall be soldered to the fitting in an approved manner, and the fitting shall be screwed to the threaded pipe.

**605.23.2 Reserved.**

**605.23.3 Stainless steel.** Joints between stainless steel and different piping materials shall be made with a mechanical joint of the compression or mechanical sealing type or a dielectric fitting.

## **SECTION PC 606**

### **INSTALLATION OF THE BUILDING WATER DISTRIBUTION SYSTEM**

**606.1 Location of full-open valves.** Full-open valves shall be installed in the following locations:

1. On the building water service pipe from the public water supply near the curb.
2. On the water distribution supply pipe at the entrance into the structure.
3. On the discharge side of every water meter.
4. On the base of every water riser pipe in occupancies other than multiple-family residential occupancies that are two stories or less in height and in one- and two-family residential occupancies.
5. On the top of every water down-feed pipe in occupancies other than one- and two-family residential occupancies.
6. On the entrance to every water supply pipe to a dwelling unit, except where supplying a single fixture equipped with individual stops.
7. On the water supply pipe to and from a gravity or pressurized water tank.

8. On the water supply pipe to every water heater.

**606.2 Location of shutoff valves.** Shutoff valves shall be installed in the following locations:

1. On the fixture supply to each plumbing fixture other than bathtubs and showers in one- and two-family residential occupancies, and other than in individual guestrooms that are provided with unit shutoff valves in hotels, motels, boarding houses and similar occupancies.
2. On the water supply pipe to each sillcock.
3. On the water supply pipe to each appliance or mechanical equipment.

**606.3 Access to valves.** Access shall be provided to all required full-open valves and shutoff valves.

**606.4 Valve identification.** Service and hose bibb valves shall be identified. All other valves installed in locations that are not adjacent to the fixture or appliance shall be identified, indicating the fixture or appliance served.

**606.5 Water pressure booster systems.** Water pressure booster systems shall be provided as required by Sections 606.5.1 through 606.5.10.

**606.5.1 Water pressure booster systems required.** Where the water pressure in the public water main or individual water supply system is insufficient to supply the minimum pressures and quantities specified in this code, the supply shall be supplemented by an elevated water tank, a hydropneumatic pressure booster system or a water pressure booster pump installed in accordance with 606.5.5.

**606.5.2 Support.** All water supply tanks shall be supported in accordance with the New York city building code.

**606.5.3 Covers.** All water supply tanks shall be covered to keep out unauthorized persons, dirt and vermin. The covers of gravity tanks shall be vented with a return bend vent pipe with an area not less than the area of the down-feed riser pipe, and the vent shall be screened with a corrosion-resistant screen of not less than 16 by 20 mesh per inch (6 by 8 mesh per cm).

**606.5.4 Overflows.** Each gravity or suction water supply tank shall be provided with an overflow not smaller than shown in Table 606.5.4(1) and/or Table 606.5.4(2) The gallons per minute listed in the tables shall be the total automatic pump capacity connected to the tank. The overflow outlet shall

discharge within 6 inches (152 mm) of a roof or roof drain, or over an open water supplied fixture. The overflow discharge shall be provided with durable screening with openings of not more than 1/8 inch.

**TABLE 606.5.4(1)**  
**SIZE OF OVERFLOWS FOR GRAVITY AND**  
**SUCTION TANKS**  
 (See Figure 606.5.4 (Single Orifice/Multiple Orifice))

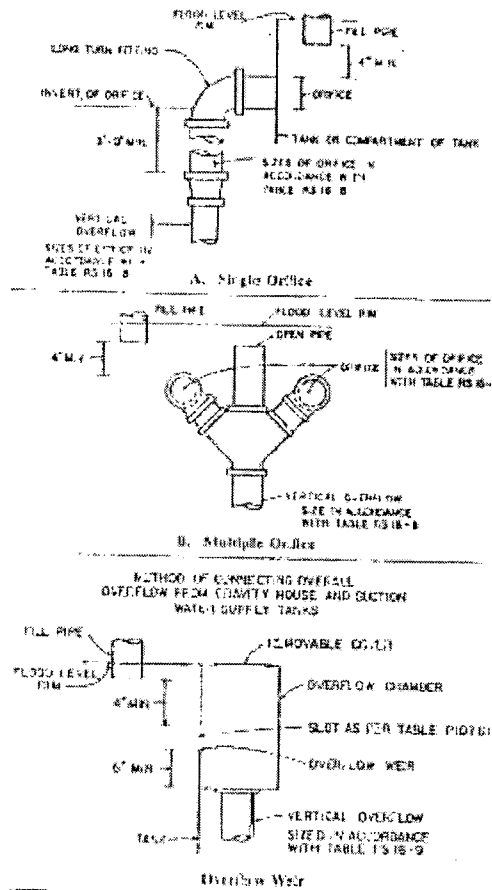
<u>OVERFLOW PIPE SIZE (inches)</u>	<u>MAXIMUM ALLOWABLE GPM FOR EACH ORIFICE OPENING INTO TANK</u>	<u>MAXIMUM ALLOWABLE GPM FOR VERTICAL OVERFLOW (PIPING CONNECTING ORIFICES)</u>
2	19	25
3	43	75
4	90	163
5	159	296
6	257	472
8	505	1,020
10	890	1,870
12	1,400	2,967

**TABLE 606.5.4(2)**  
**SIZE OF WEIRS FOR GRAVITY AND SUCTION TANKS**  
 (See Figure (Overflow Weir))

<u>SLOTTED WEIR OPENING INTO TANK BETWEEN OVERFLOW CHAMBER AND WATER COMPARTMENT *</u>	<u>MAXIMUM GPM ALLOWABLE FOR WEIR</u>
3 inches x 24 inches	381
3 1/2 inches x 24 inches	475
4 1/2 inches x 24 inches	685
4 1/2 inches x 36 inches	1,037
6 inches x 36 inches	1,569
6 inches x 48 inches	2,100

a. Bottom of the overflow chamber must be at least 6 inches below weir.

b. Bottom outlet shall be provided in the chamber of sizes based on capacities as indicated in Table 606.5.4(1).



**606.5.4.1 Water piping control and location.** Water inlets to gravity house tanks shall be controlled by a ball cock or other automatic supply valve or emergency electrical cut-off so installed as to prevent the overflow of the tank in the event that the pumps filling the tanks do not shut off at the predetermined level or the street pressure rises to a point where it can fill the tank. The water inlet to a suction tank shall be controlled by a ball cock or other automatic supply valve. The inlet shall be terminated so as to provide an accepted air gap but in no case shall it be less than 4 inches (102 mm) above the top of the overflow. The outlet from a gravity tank to the distribution system shall be equipped with a strainer located at least 2 inches (51 mm) above the tank bottom to prevent solids from entering the piping system. All down-feed supplies from a tank cross-connected in any manner with distribution supply piping in a building supplied by direct street or pump pressure, shall be equipped with a check valve on the main cold water down supply to prevent backflow of water into the roof tank.

**606.5.4.2 Drain pipes for emptying tanks.** Each tank or tank compartment shall be provided, at its lowest point, with a valved pipe to permit emptying the tank. The drain pipe shall discharge as required for the overflow pipe, and shall be at least 4 inches (102 mm) in diameter.

**606.5.4.3 Prohibited location.** Potable water gravity tanks or manholes of potable water pressure tanks shall not be located directly under any soil or waste piping.

**606.5.4.4 Design.** The gravity house supply tank shall be built of wood, steel, or equivalent materials. Subject to the approval of the Commissioner, additional linings may be installed in the tank, provided the lining material does not have a toxic or otherwise objectionable effect on the potable water. Steel tanks shall be painted both inside and outside. If a tank with a dividing partition is installed, the total capacity of the combined compartments shall be considered as the capacity of a single tank for the purpose of determining storage capacities of the tank.

**606.5.4.5 Cleaning or painting.** Water tanks shall be cleaned and painted in accordance with the following:

1. No water tank of any kind that is part of a building water supply system used for potable



purposes shall be cleaned with any material or painted on the inside with any material that will have a toxic or otherwise objectionable effect on the potability of the water supply when the tank is put into service. No lead paint shall be used. The water supply connections to and from a tank shall be disconnected or plugged while the tank is being cleaned or painted to prevent any foreign fluid or substance from entering the distribution piping. Where the air in a tank may be insufficient to sustain human life, or may contain an injurious gas, adequate measures shall be taken for the protection of the workers.

2. After the tank has been cleaned or painted, it shall be disinfected according to the following procedure before it is put back in service:

2.1. The underside of the top, the bottom, and the walls shall be washed with a hypochlorite solution containing 100 or more parts per million of available chlorine.

2.2. The tank shall be filled with water to which hypochlorite solution is added during the filling in sufficient quantity so that the treated water in the tank will contain at least 10 parts per million of available chlorine.

2.3. The chlorinated water shall be allowed to remain in the tank for two hours.

2.4. Finally, the tank shall be drained completely before refilling.

3. House and suction tanks shall be drained and cleaned at least once a year.

**606.5.5 Low-pressure cutoff required on booster pumps.** A low-pressure cutoff shall be installed on all booster pumps in a water pressure booster system to prevent creation of a vacuum or negative pressure on the suction side of the pump when a positive pressure of 10 psi (68.94 kPa) or less occurs on the suction side of the pump.

**606.5.6 and 606.5.7 Reserved.**

**606.5.8 Prohibited location of potable supply tanks.** Potable water gravity tanks or manholes of potable water pressure tanks shall not be located directly under any soil or waste piping or any source of contamination.

**606.5.9 Pressure tanks, vacuum relief.** All water pressure tanks shall be provided with a vacuum relief

valve at the top of the tank that will operate up to a maximum water pressure of 200 psi (1380 kPa) and up to a maximum temperature of 200°F (93°C). The minimum size of such vacuum relief valve shall be 0.50 inch (12.7 mm).

**Exception:** This section shall not apply to pressurized captive air diaphragm/bladder tanks.

**606.5.10 Pressure relief for tanks.** Every pressure tank in a hydropneumatic pressure booster system shall be protected with a pressure relief valve. The pressure relief valve shall be set at a maximum pressure equal to the rating of the tank. The relief valve shall be installed on the supply pipe to the tank or on the tank. The relief valve shall discharge by gravity to a safe place of disposal.

**606.6 Water supply system test.** Upon completion of a section of or the entire water supply system, the system, or portion completed, shall be tested in accordance with Section PC 312.

## **SECTION PC 607**

### **HOT WATER SUPPLY SYSTEM**

**607.1 Where required.** In residential occupancies, hot water shall be supplied to all plumbing fixtures and equipment utilized for bathing, washing, culinary purposes, cleansing, laundry or building maintenance. In nonresidential occupancies, hot water shall be supplied to all plumbing fixtures and equipment utilized for culinary purposes, cleansing, laundry or building maintenance. In nonresidential occupancies, hot water or tempered water shall be supplied for bathing and washing purposes. Tempered water shall be delivered for accessible hand-washing facilities.

**607.2 Hot water supply temperature maintenance.** Where the developed length of hot water piping from the source of hot water supply to the farthest fixture exceeds 20 feet (6096 mm), the hot water supply system shall be provided with a method of maintaining the temperature in accordance with the New York state energy conservation construction code.

**607.2.1 Piping insulation.** Circulating hot water system piping shall be insulated in accordance with the New York state energy conservation construction code.

**607.2.2 Hot water system controls.** Automatic circulating hot water system pumps or heat trace shall be arranged to be conveniently turned off, automatically or

manually, when the hot water system is not in operation.

**607.2.3 Recirculating pump.** Where a thermostatic mixing valve is used in a system with a hot water recirculating pump, the hot water or tempered water return line shall be routed to the cold water inlet pipe of the water heater and the cold water inlet pipe or the hot water return connection of the thermostatic mixing valve.

**607.3 Thermal expansion control.** A means of controlling increased pressure caused by thermal expansion shall be provided where required in accordance with Sections 607.3.1 and 607.3.2.

**607.3.1 Pressure-reducing valve.** For water service system sizes up to and including 2 inches (51 mm), a device for controlling pressure shall be installed where, because of thermal expansion, the pressure on the downstream side of a pressure-reducing valve exceeds the pressure-reducing valve setting.

**607.3.2 Backflow prevention device or check valve.** Where a backflow prevention device, check valve or other device is installed on a water supply system utilizing storage water heating equipment such that thermal expansion causes an increase in pressure, a device for controlling pressure shall be installed.

**607.4 Flow of hot water to fixtures.** Fixture fittings, faucets and diverters shall be installed and adjusted so that the flow of hot water from the fittings corresponds to the left-hand side of the fixture fitting.

**Exception:** Shower and tub/shower mixing valves conforming to ASSE 1016, where the flow of hot water corresponds to the markings on the device.

## **SECTION PC 608** **PROTECTION OF POTABLE WATER SUPPLY**

**608.1 General.** A potable water supply system shall be designed, installed and maintained in such a manner so as to prevent contamination from nonpotable liquids, solids or gases being introduced into the potable water supply through cross-connections or any other piping connections to the system. Backflow preventer applications shall conform to Table 608.1, except as specifically stated in Sections 608.2 through 608.16.9.

**TABLE 608.1**  
**APPLICATION OF BACKFLOW PREVENTERS**



## CPVC 2006

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**From:** Cash, Jeff [Jeff.Cash@Noveon.com]  
**Sent:** Thursday, February 23, 2006 2:24 PM  
**To:** CPVC 2006  
**Subject:** RE: One more market question  
**Importance:** High

Robin:

I seem to be having problems with my calculator today. If you receive an earlier response to this, please disregard it. I had an error in the market size and in CPVC because I overestimated commercial potable water share.

We estimate that the total North American potable water market is approximately 230 million pounds, as measured as CPVC (since copper is heavier per foot of pipe, pounds as measured by copper would be much greater.)

I mention total North America since we don't actually sell the pipe, we don't have a perfect window into how much is Canada vs. US vs. Mexico. A good estimate is 80% USA, 10% Canada and 10% Mexico.

Of the total 230 million pounds:

- CPVC is about **70** million, or **30%**
- PEX is about 40 million, or 17%
- Copper is the rest, or **53%**

PVC is not used in potable water.

There are a lot of regional differences in the above ratios, as you might expect, but we would not have hard data. For example, Florida is a very heavy CPVC user while as you might imagine California is not.

I trust this helps. Let me know how else we can be of assistance.

Jeff



**Robin Gilb**

---

**From:** Robin Gilb  
**Sent:** Monday, February 27, 2006 8:14 AM  
**To:** 'Bob Raymer'  
**Subject:** RE: One more question

Thank you Bob, this is very helpful.  
Robin

---

**From:** Bob Raymer [mailto:rraymer@cbia.org]  
**Sent:** Friday, February 24, 2006 7:46 PM  
**To:** Robin Gilb  
**Subject:** RE: One more question

The "ballpark" estimate I have is that the total North American potable water pipe market is approximately 230 million pounds, as measured as CPVC (since copper is heavier per foot of pipe, pounds as measured by copper would be much greater.)

Of the North American market, a good estimate is 80% USA, 10% Canada and 10% Mexico.

Of the total 230 million pounds:

- CPVC is about 90 million, or 39%
- PEX is about 40 million, or 17%
- Copper is the rest, or 44%

PVC is not used in potable water.

There are a lot of regional differences in the above ratios, as you might expect, but we would not have hard data. For example, Florida is a very heavy CPVC user while as you might imagine California is not.

One thing is very clear; the existing multifamily housing stock (apartments primarily) in California will be needing extensive plumbing system rehab in the coming years. The units built in the 1950's through the 1970's will be needing substantial (and expected) rehab. Many of these rehab projects will be indefinitely postponed if allowable materials are limited to metal

pipe. Regarding metal pipes, the labor costs associated with the time-intensive rehab of existing multi-family dwellings are simply too high to make many projects economically viable.

---

**From:** Robin Gilb [mailto:rgilb@hcd.ca.gov]  
**Sent:** Thu 2/23/2006 8:58 AM  
**To:** Bob Raymer  
**Subject:** One more question

Bob,

I have another question that you may be able to answer for me....

What is the estimated US market share of CPVC (from all manufacturers) in the potable water plumbing market? I'm guessing copper is a major share of the market, so the type of information I'm looking for is something like, "copper is 70% of the market and CPVC is 20% and PVC is 10%."

Thank you,  
Robin

**Robin Gilb, Staff Counsel**  
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Fax: (916) 323-2815

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RG. 219  
Doc. 219

**Robin Gilb**

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**From:** Bob Raymer [rraymer@cbia.org]  
**Sent:** Wednesday, March 22, 2006 7:47 AM  
**To:** Robin Gilb  
**Subject:** RE: Information for CPVC EIR

1. What amount of cement would be used (one-step) for fictional house/unit?

For a 2,000 sq ft home approx 3-1/2 pints of 1-step cement .

2. How many re-pipes each year see below:

Re-pipe numbers and Re-hab numbers are as follows. Re-hab usually includes units for re-piping.

NOTE: THESE ARE ONLY ESTIMATES.

Southern California re-pipe market.....	50,000 units
Northern California re-pipe market .....	15,000 units
Southern California Re-Hab Market.....	25,000 units
Northern California Re-Hab Market.....	10,000 units
Total Unit potential.....	100,000 units.

Another topic is slab leaks where only partial re-pipes are being done and this could also be a very large quantity with probable 200,000 leaks per year in southern and Northern Cal. This would be one line re-route or repair.

3. What type of year is used : I'll get back to you on this one.

---

**From:** Robin Gilb [mailto:rgilb@hcd.ca.gov]  
**Sent:** Tue 3/21/2006 2:49 PM  
**To:** Bob Raymer  
**Subject:** FW: Information for CPVC EIR

Bob:



**EXPRESS TERMS  
FOR  
PROPOSED BUILDING STANDARDS  
OF THE  
DEPARTMENT OF HOUSING AND COMMUNITY DEVELOPMENT  
REGARDING THE ADOPTION BY REFERENCE OF THE  
2006 EDITION OF THE UNIFORM PLUMBING CODE (UPC) WITH PROPOSED AMENDMENTS  
INTO THE 2007 CALIFORNIA PLUMBING CODE (CPC)  
CALIFORNIA CODE OF REGULATIONS, TITLE 24, PART 5**

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The Department of Housing and Community Development (HCD) proposes to adopt the 2006 edition of the Uniform Plumbing Code (UPC) for codification and effectiveness into the 2007 edition of the California Plumbing Code (CPC) as presented on the following pages, including any necessary amendments. HCD further proposes to:

- Repeal the 2000 edition of the Uniform Plumbing Code;
- Repeal amendments to the model codes that are no longer necessary, repeal or amend building standards that are not addressed by a model code;
- Relocate or codify existing adopted and necessary amendments to the model code into the format of the model code proposed for adoption, the action of which has no regulatory effect; adopt new necessary amendments to the model code proposed for adoption; and/or
- Adopt new building standards that are not addressed by the model code proposed for adoption

---

**LEGEND FOR EXPRESS TERMS:**

1. Existing California amendments or code language being modified: All such language appears in *italics*, modified language is underlined or shown in ~~strikeout~~.
  2. New UPC language with new California amendments: UPC language shown in normal Arial 9 point; California amendments to UPC text shown underlined and in italics.
  3. Repealed text: All such language appears in ~~strikeout~~.
  4. Notation: Authority and Reference citations are provided at the end of each chapter.
- 

**HCD PROPOSES TO REPEAL EXISTING AMENDMENTS AND/OR CALIFORNIA BUILDING STANDARDS NOT ADDRESSED BY MODEL CODES THAT ARE NO LONGER NECESSARY AS FOLLOWS:**

**REPEALED AMENDMENTS:**

~~101.1.2 [For HCD 1 & HCD 2] California Plumbing Code. This document shall be known as the "California Plumbing Code." Where a reference to the Uniform Plumbing Code or UPC appears in the text of this code, the reader shall understand the reference to be to the California Plumbing Code at Part 5 of Title 24, California Code of Regulations. The provisions contained in the California Plumbing Code of the (compiled) California Building Standards Code as defined in Section 18910, Health and Safety Code, may be cited as such and are referred to hereafter as "these regulations", "these plumbing standards" or "this code".~~

~~101.2.2 [For HCD 1 & HCD 2] California Purpose. To provide minimum standards to safeguard life or limb, health, property and public welfare, and protect against hazards that may arise from the use of plumbing piping and systems by regulating and controlling the design, construction, installation, quality of materials, location and operation of plumbing piping systems within the State of California.~~

~~101.4.0 [For HCD 1 & HCD 2] Application. The provisions of this code shall apply to the construction, alteration, moving, demolition, repair and use of all plumbing, gas, or drainage piping and systems or water heating or treating equipment in or on any building or structure or outdoors on any premises or property.~~

Water Closet, 1.6 GPF Flushometer Tank .....	1/2"	2.5	2.5	3.5
Water Closet, 1.6 GPF Flushometer Valve .....	1"	See Footnote 7		
Water Closet, greater than 1.6 GPF Gravity Tank.....	1/2"	3.0	5.5	7.0
Water Closet, greater than 1.6 GPF Flushometer Valve.....	1"	See Footnote 7		

**Notes:**

1. Size of the cold branch pipe, or both the hot and cold branch pipes.
2. Appliances, Appurtenances or Fixtures not included in this Table may be sized by reference to fixtures having a similar flow rate and frequency of use.
3. The listed fixture unit values represent their load on their cold water service. The separate cold water and hot water fixture unit value for fixtures having both hot and cold water connections may each be taken as three-quarter (3/4) of the listed total value of the fixture.
4. The listed minimum supply branch pipe sizes for individual fixtures are the nominal (I.D.) pipe size.
5. For fixtures or supply connections likely to impose continuous flow demands, determine the required flow in gallons per minute (GPM) and add it separately to the demand (in GPM) for the distribution system or portions thereof.
6. Assembly [Public Use (See Table 4-1)].
7. When sizing flushometer systems see Section 610.10.
8. Reduced fixture unit loading for additional hose bibbs as used is to be used only when sizing total building demand and for pipe sizing when more than one hose bibb is supplied by a segment of water distributing pipe. The fixture branch to each hose bibb shall be sized on the basis of 2.5 fixture units.
9. For fixture unit values related to manufactured housing (mobilehomes) in all parts of the State of California, See California Code of Regulations, Title 25, Division 1, Chapter 2, Article 5, Section 1278. For fixture unit values related to Special Occupancy Parks in all parts of the State of California, See California Code of Regulations, Title 25, Division 1, Chapter 2.2, Article 5, Section 2278.

**NOTE:**

Authority: Health and Safety Code Sections 17040, 17921, 17922, 18300, 18865 and 19990; and Government Code Sections 12955.1 and 12955.1.1.

Reference: Health and Safety Code Sections 17000 through 17060, 17910 through 17995.5, 18630, 18640, 18690, 18873.1, 18873.2, 18873.4 and 19960 through 19997; and Government Code Sections 12955.1 and 12955.1.1.

## CHAPTER 7 SANITARY DRAINAGE

Adopt entire Chapter 7 as amended.

**701.1.2.2 [For HCD 1 & HCD 2]** ~~ABS and PVC installations are limited to not more than two stories of areas of residential accommodation.~~

**TABLE 7-3**

Drainage Fixture Unit Values (DFU)

	Min. Size Trap and Trap Arm <sup>7</sup>	Private	Public	Assembly <sup>8</sup>
Plumbing Appliance, Appurtenance or Fixture				
Bathtub or Combination Bath/Shower .....	1-1/2"	2.0	2.0	
Bidet.....	1-1/4"	1.0		
Bidet.....	1-1/2"	2.0		
Clothes Washer, domestic, standpipe <sup>5</sup> .....	2"	3.0	3.0	3.0
Dental Unit, cuspidor .....	1-1/4"		1.0	1.0
Dishwasher, domestic, with independent drain .....	1-1/2" <sup>2</sup>	2.0	2.0	2.0
Drinking Fountain or Watercooler (per head) .....	1-1/4"	0.5	0.5	1.0
Food-waste-grinder, commercial .....	2"		3.0	3.0
Floor Drain, emergency.....	2"		0.0	0.0
Floor Drain (for additional sizes see Section 702) .....	2"	2.0	2.0	2.0
Shower single head trap .....	2"	2.0	2.0	2.0
Multi-head, each additional .....	2"	1.0	1.0	1.0
Lavatory, single.....	1-1/4"	1.0	1.0	1.0
Lavatory in sets of two or three.....	1-1/2"	2.0	2.0	2.0
Washfountain.....	1-1/2"		2.0	2.0
Washfountain.....	2"		3.0	3.0

**Exception:** ~~[For HCD 1 & HCD 2]~~ For applications listed in 108.2.1 through 108.2.1.3 regulated by the Department of Housing and Community Development, compliance with an approved nationally recognized installation standard complying with Section 310.4 of this code and approved by the Administrative Authority Enforcing Agency is acceptable.

**705.2.5** ~~[For HCD 1 & HCD 2]~~ **ABS and PVC Pipe.** For applications listed in 108.2.1 through 108.2.1.3 regulated by the Department of Housing and Community Development, joints in ABS and PVC pipe shall be made as provided in Section 316.0, U.P.C 316.1.6 of this code.

**710.3.3.1** ~~[For HCD 1 & HCD 2]~~ For applications listed in 108.2.1 through 108.2.1.3 regulated by the Department of Housing and Community Development, The the minimum size of any pump or any discharge pipe from a sump having a water closet connected thereto shall be not less than (2) inches (51 mm).

**NOTE:**

Authority: Health and Safety Code Sections 17040, 17921, 17922, 18300, 18865 and 19990; and Government Code Sections 12955.1 and 12955.1.1.

Reference: Health and Safety Code Sections 17000 through 17060, 17910 through 17995.5, 18630, 18640, 18690, 18873.1, 18873.2, 18873.4 and 19960 through 19997; and Government Code Sections 12955.1 and 12955.1.1.

**CHAPTER 8  
INDIRECT WASTES**

Adopt entire Chapter 8 without amendments.

**NOTE:**

Authority: Health and Safety Code Sections 17040, 17921, 17922, 18300, 18865 and 19990; and Government Code Sections 12955.1 and 12955.1.1.

Reference: Health and Safety Code Sections 17000 through 17060, 17910 through 17995.5, 18630, 18640, 18690, 18873.1, 18873.2, 18873.4 and 19960 through 19997; and Government Code Sections 12955.1 and 12955.1.1.

**CHAPTER 9  
VENTS**

Adopt entire Chapter 9 as amended.

**903.1.2.2** ~~[For HCD 1 & HCD 2]~~ **ABS or PVC installations are limited to not more than two stories of areas of residential accommodation.**

**903.3.1** ~~[For HCD 1 & HCD 2]~~ For applications listed in 108.2.1 through 108.2.1.3 regulated by the Department of Housing and Community Development, All all malleable iron vents shall be galvanized.

**NOTE:**

Authority: Health and Safety Code Sections 17040, 17921, 17922, 18300, 18865 and 19990; and Government Code Sections 12955.1 and 12955.1.1.

Reference: Health and Safety Code Sections 17000 through 17060, 17910 through 17995.5, 18630, 18640, 18690, 18873.1, 18873.2, 18873.4 and 19960 through 19997; and Government Code Sections 12955.1 and 12955.1.1.

**CHAPTER 10  
TRAPS AND INTERCEPTORS**

Adopt entire Chapter 10 as amended.

**1005.0 Trap Seals.** Each fixture trap shall have a water seal of not less than two (2) inches (51 mm) and not more than four (4) inches (102 mm) except where a deeper seal is found necessary by the Authority Having Jurisdiction. Traps shall be set true with respect to their water seals and, where necessary, they shall be protected from freezing.

~~[For HCD 1/AC & HCD 2] Reference Section 101.11 and California Code of Regulations, Title 24, Part 2, Chapter 11A, Housing Accessibility, for disabled access application and requirements. The terminology "persons with disabilities" has replaced the usage of the outdated and incorrect term "handicapped" listed above.~~

net capacity of one (1) cubic foot (0.03 m<sup>3</sup>) for each one hundred (100) square feet (9.3 m<sup>2</sup>) of surface to be drained into the interceptor, with a minimum of six (6) cubic feet (0.2 m<sup>3</sup>).

**NOTE:**

Authority: Health and Safety Code Sections 17040, 17921, 17922, 18300, 18865 and 19990; and Government Code Sections 12955.1 and 12955.1.1.

Reference: Health and Safety Code Sections 17000 through 17060, 17910 through 17995.5, 18630, 18640, 18690, 18873.1, 18873.2, 18873.4 and 19960 through 19997; and Government Code Sections 12955.1 and 12955.1.1.

## **CHAPTER 11 STORM DRAINAGE**

Adopt entire Chapter 11 as amended.

**1101.1 [Not Adopted by HCD] Where Required.** All roofs, paved areas, yards, courts, and courtyards shall be drained into a separate storm sewer system, or into a combined sewer system where a separate storm sewer system is not available, or to some other place of disposal satisfactory to the Authority Having Jurisdiction. In the case of one- and two-family dwellings, storm water may be discharged on flat areas such as streets or lawns so long as the storm water shall flow away from the building and away from adjoining property, and shall not create a nuisance.

~~**1101.1.1 [For HCD 1 & HCD 2] Where Required.** All roofs, paved areas, yards, courts, and courtyards shall be drained into a separate storm sewer system. Where a separate storm sewer system is not available, drainage may be combined in the sanitary sewer system, or to some other place of disposal satisfactory to and approved by the Administrative Authority in the case of one- and two-family dwellings, storm water may be discharged on flat areas such as streets or lawns so long as the storm water shall flow away from the building and away from adjoining property, and shall not create a nuisance.~~

~~**1101.3.1 [For HCD 1 & HCD 2] Material Uses.** Rainwater piping placed within the interior of a building or run within a vent or shaft shall be of cast iron, galvanized steel, wrought iron, brass, copper, lead, Schedule 40 ABS DWV, Schedule 40 PVC DWV, stainless steel 304 or 316L (stainless steel 304 pipe and fittings shall not be installed underground and shall be kept at least six inches (152 mm) above ground), or other approved materials, and changes in direction shall conform to the requirements of Section 706.0. ABS or PVC installations are limited to not more than two stories of areas of residential accommodation.~~

~~**1101.3.3 [For HCD 1 & HCD 2]** ABS or PVC installations are limited to not more than two stories of areas of residential accommodation.~~

### **1101.5 Subsoil Drains.**

**1101.5.1** Subsoil drains shall be provided around the perimeter of buildings having basements, cellars, or crawl spaces or floors below grade. Such subsoil drains may be positioned inside or outside of the footing, shall be of perforated or open-jointed approved drain tile or pipe not less than three (3) inches (80 mm) in diameter, and shall be laid in gravel, slag, crushed rock, approved three-quarter (3/4) inch (19.1 mm) crushed recycled glass aggregate, or other approved porous material with a minimum of four (4) inches (102 mm) surrounding the pipe on all sides. Filter media shall be provided for exterior subsoil piping.

~~**1101.5.1.1 [For HCD 1 & HCD 2] Exception:** For applications listed in 108.2.1 through 108.2.1.3 regulated by the Department of Housing and Community Development, subsoil drains are mandatory only when when required by the Administrative Authority due to geological conditions, subsoil drains shall be provided around the perimeter of buildings having basement, cellars, or crawl spaces or floors below grade. Such subsoil drains may be positioned inside or outside of the footing, shall be of perforated, or open-jointed approved drain tile or pipe not less than three (3) inches (76 mm) in diameter, and shall be laid in gravel, slag, crushed rock, approved three-quarter (3/4) inch (19.1 mm) crushed recycled glass aggregate, or other approved porous material with a minimum of four (4) inches (102 mm) surrounding the pipe on all sides. Filter media shall be provided for exterior subsoil piping.~~

### **1102.1.2**

The inside of conductors installed above ground level shall be of seamless copper water tube, Type K, L, or M; Schedule 40 copper pipe or Schedule 40 copper alloy pipe; Type DWV copper drainage tube; service weight cast-iron soil pipe or hubless cast-iron soil pipe; standard weight galvanized steel pipe; Stainless Steel 304 or 316L (stainless steel 304 pipe and fittings shall not be installed underground and shall be kept at least six inches (152 mm) above ground); or Schedule 40 ABS or Schedule 40 PVC plastic pipe.

~~[For HCD 1 & HCD 2] ABS or PVC installations are limited to not more than two stories of areas of residential accommodation.~~

**NOTE:**

Authority: Health and Safety Code Sections 17040, 17921, 17922, 18300, 18865 and 19990; and Government Code Sections 12955.1 and 12955.1.1.

Reference: Health and Safety Code Sections 17000 through 17060, 17910 through 17995.5, 18630, 18640, 18690, 18873.1, 18873.2, 18873.4 and 19960 through 19997; and Government Code Sections 12955.1 and 12955.1.1.

**CHAPTER 12  
FUEL PIPING**

Adopt entire Chapter 12 as amended.

**1216.4** The size of the supply piping outlet for any gas appliance shall not be less than one-half (1/2) inch (12.7mm). ~~[The following sentence is no adopted by HCD]~~ The minimum size of any piping outlet for a mobile home shall be three-quarter (3/4) inch (19.1 mm).

~~Fuel piping for manufactured homes, mobilehomes, and recreational vehicles are sized in accordance with California Code of Regulations, Title 25, Chapter 3 and the California Health and Safety Code, Division 13, Part 2, Mobilehome/Manufactured Housing Act of 1980.~~

**1216.4.1** ~~[For HCD 1 & HCD 2] Fuel Piping for Manufactured Homes, Mobilehomes, and Recreational Vehicles.~~ ~~Fuel piping for manufactured homes mobilehomes, and recreational vehicles are sized in accordance with California Code of Regulations, Title 25, Chapter 3 and the California Health and Safety Code, Division 13, Part 2, Mobilehome/Manufactured Housing Act of 1980.~~

**NOTE:**

Authority: Health and Safety Code Sections 17040, 17921, 17922, 18300, 18865 and 19990; and Government Code Sections 12955.1 and 12955.1.1.

Reference: Health and Safety Code Sections 17000 through 17060, 17910 through 17995.5, 18630, 18640, 18690, 18873.1, 18873.2, 18873.4 and 19960 through 19997; and Government Code Sections 12955.1 and 12955.1.1.

**CHAPTER 13  
HEALTH CARE FACILITIES AND MEDICAL GAS AND VACUUM SYSTEMS**

Chapter 13 is not adopted.

**NOTE:**

Authority: Health and Safety Code Sections 17040, 17921, 17922, 18300, 18865 and 19990; and Government Code Sections 12955.1 and 12955.1.1.

Reference: Health and Safety Code Sections 17000 through 17060, 17910 through 17995.5, 18630, 18640, 18690, 18873.1, 18873.2, 18873.4 and 19960 through 19997; and Government Code Sections 12955.1 and 12955.1.1.

**CHAPTER 14  
MANDATORY REFERENCED STANDARDS**

Adopt entire Chapter 14 without amendments.

**NOTE:**

Authority: Health and Safety Code Sections 17040, 17921, 17922, 18300, 18865 and 19990; and Government Code Sections 12955.1 and 12955.1.1.

Reference: Health and Safety Code Sections 17000 through 17060, 17910 through 17995.5, 18630, 18640, 18690, 18873.1, 18873.2, 18873.4 and 19960 through 19997; and Government Code Sections 12955.1 and 12955.1.1.





[Federal Register: August 22, 1997 (Volume 62, Number 163)]  
[Notices]  
[Page 44684-44685]  
From the Federal Register Online via GPO Access [waiss.access.gpo.gov]  
[DOCID:fr22au97-88]

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## ENVIRONMENTAL PROTECTION AGENCY

[FRL-5880-2]

Interpretation of New Drinking Water Requirements Relating to  
Lead Free Plumbing Fittings and Fixtures

AGENCY: Environmental Protection Agency (EPA).

ACTION: Notice.

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SUMMARY: Section 1417(a)(3) of the Safe Drinking Water Act (SDWA), as amended makes it unlawful for any person to introduce into commerce after August 6, 1998 any pipe, or any pipe or plumbing fitting or fixture that is not lead free. In section 1417(e) as added by the 1996 SDWA Amendments, Congress directed EPA to provide assistance for the development of voluntary standards and testing protocols for the leaching of lead from new plumbing fittings and fixtures relating to drinking water. This notice confirms EPA's position that performance standards for the leaching of lead from new plumbing fittings and fixtures have been established, as directed by the SDWA.

The SDWA requires that, if a voluntary standard for the leaching of lead from new plumbing fittings and fixtures is not established by August 1997, then EPA must promulgate regulations setting a performance based standard for lead leaching from such components. The National Sanitation Foundation (**NSF**) established a voluntary standard, **NSF** Standard 61, section 9, governing the leaching of lead

[[Page 44685]]

from new plumbing fittings and fixtures in September 1994. EPA participated in the development of the **NSF** Standard because the Agency felt that, rather than promulgating a regulation, limiting the amount of lead leaching from brass and other alloys into drinking water would be best achieved through a voluntary standard, which is fully protective on a health basis and technologically achievable by industry in a reasonable period of time. In the Agency's view, **NSF** Standard 61, section 9 satisfies the requirement of section 1417(e), that a voluntary standard be established. Thus, the obligation to issue regulations is not triggered. See S. Rep. 104-169 ``104th Cong.), at 95.'' Copies of **NSF** Standard 61, and the listings of products meeting this standard may be obtained from **NSF** International, 3475 Plymouth Road, PO Box 130140, Ann Arbor, MI 48113-0140. The telephone number is 313-769-8010.

FOR FURTHER INFORMATION CONTACT: Peter Lassoovszky, Office of Ground Water and Drinking Water (4607), U.S. Environmental Protection Agency, 401 M Street, SW., Washington, DC. For further information, call the U.S. EPA Safe Drinking Water Hotline between 8:30 am and 5 pm Eastern Time, Monday through Friday excluding Federal holidays, by telephoning toll-free 1-800-426-4791 nationwide.

Dated: August 13, 1997.  
Robert Perciasepe,  
Assistant Administrator, Office of Water.  
[FR Doc. 97-22360 Filed 8-21-97; 8:45 am]  
BILLING CODE 6560-50-P

## NOTICES

## ENVIRONMENTAL PROTECTION AGENCY

[OW-FRL-3410-1]

## Drinking Water Technical Assistance; Termination of the Federal Drinking Water Additives Program

Thursday, July 7, 1988

\*25586 AGENCY: Environmental Protection Agency (EPA).

ACTION: Notice.

SUMMARY: The Environmental Protection Agency (EPA), Office of Drinking Water (ODW), has operated an advisory program that gives technical assistance to concerned parties on the use of drinking water additives. On May 17, 1984, EPA proposed to terminate major elements of this Federal program and to assist in the establishment of a private-sector program which would offer assistance in evaluating drinking water additives. 49 FR 21004. EPA solicited proposals from qualified nongovernmental, nonprofit organizations for assistance under a cooperative agreement to establish a credible and efficient program in the private sector.

On September 17, 1985, EPA selected a consortium consisting of the National Sanitation Foundation (NSF), the American Water Works Association Research Foundation (AWWARF), the Conference of State Health and Environmental Managers (COSHEM), and the Association of State Drinking Water Administrators (ASDWA) to receive funds under a cooperative agreement to develop the private-sector program. EPA believes that the NSF-led program has proceeded satisfactorily. NSF Standard 60, covering many direct additives, was adopted on December 7, 1987; and NSF Standard 61, covering indirect additives, was adopted on June 3, 1988. Other standards are forthcoming. The NSF-led program has begun offering testing, certification, and listing services, as described in 49 FR 21004, for certain classes of products covered by these standards. Accordingly, as the NSF-led program becomes operational, EPA will phase out its activities in this area, as described in this notice.

DATE: Any written comments on implementing this notice should be submitted to the address below by September 6, 1988.

ADDRESSES: Submit comments to: Mr. Arthur H. Perler, Chief, Science and Technology Branch, Office of Drinking Water (WH-550D), U.S. Environmental Protection Agency, 401 M Street, SW., Washington, DC 20460. A copy of all comments will be available for review during normal business hours at the U.S. Environmental Protection Agency, Criteria and Standards Division, Science and Technology Branch, Room 931ET, 401 M Street, SW., Washington, DC 20460. For further information on the NSF-led private-sector program, including standards development and testing, certification, and listing services, contact: Director, Drinking Water Additives Program, National Sanitation Foundation, P.O. Box 1468, Ann Arbor, MI 48106; or call (313) 769-8010.

For information on alternative testing, certification, and listing programs, contact individual State regulatory authorities or the American Water Works Association, Technical and Professional Department, 6666 Quincy Avenue, Denver CO, 80235, or call (303) 794-7711. For information on the directory of products certified as meeting the criteria in a NSF standard, contact the American Water Works Association Research Foundation, 6666 Quincy Avenue, Denver CO, 80235, or call (303) 794-7711.

FOR FURTHER INFORMATION CONTACT: Mr. Arthur H. Perler, Chief, Science and Technology Branch, Office of Drinking Water (WH-550D), U.S. Environmental Protection Agency, 401 M Street, SW., Washington, DC 20460, or call (202) 382- 2022.

## I. Introduction

The Safe Drinking Water Act (SDWA) (42 U.S.C. 300f et seq.) provides for enhancement of the safety of public drinking water supplies through the establishment and enforcement of national drinking water regulations. The Environmental Protection Agency (EPA) has the primary responsibility for establishing the regulations, and the States have the primary responsibility for enforcing such regulations. The regulations control contaminants in drinking water which may have any adverse effect on public health. Section 1412, 42 U.S.C. 300g-1. The regulations include maximum contaminant levels (MCLs) or treatment techniques and monitoring requirements for these contaminants. Sections 1401 and 1412; 42 U.S.C. 300f and 300g-1. EPA also promulgates monitoring requirements for unregulated contaminants. Section 1445; 42 U.S.C. 300j-4. In addition, EPA has broad authorities to provide technical assistance and financial assistance (e.g., grants, cooperative agreements) to States and to conduct research. Sections 1442, 1443, 1444; 42 U.S.C. 300j-1, 300j-2, 300j-3.

The Agency has established MCLs for a number of harmful contaminants that occur naturally or pollute public drinking water supplies. In addition to such contaminants, there is a possibility that drinking water supplies may be contaminated by compounds "added" to drinking water, either directly or indirectly, in the course of treatment and transport of drinking water. Public water systems use a broad range of chemical products to treat water supplies and to maintain storage and distribution systems. For instance, systems may directly add chemicals such as chlorine, alum, lime, and coagulant aids in the process of treating water to make it suitable for public consumption. These are known as "direct additives." In addition, as a necessary function of maintaining a public water system, storage and distribution systems (including pipes, tanks, and other equipment) may be fabricated from or painted, coated, or treated with products which may leach into or otherwise enter the water. These products are known as "indirect additives." Except to the extent that direct or indirect additives consist of ingredients or contain contaminants for which EPA has promulgated MCLs, EPA does not currently regulate the levels of additives in drinking water.

In 1979, EPA executed a Memorandum of Understanding (MOU) with the U.S. Food and Drug Administration (FDA) to establish and clarify areas of authorities with respect to control of additives in drinking water. 44 FR 42775, July 20, 1979. FDA is authorized to regulate "food additives" pursuant to the Federal Food, Drug, and Cosmetic Act (FFDCA). (21 U.S.C. 301 et seq.). Both agencies acknowledged in the MOU that "passage of the SDWA in 1974 repealed FDA's authority under the FFDCA

over water used for drinking water purposes." The MOU stated that FDA would continue to have authority for taking regulatory action under the FFDCA to control additives in bottled drinking water and in water used in food and for food processing. The MOU went on to say that EPA had authority to control additives in public drinking water supplies.

While the SDWA does not require EPA to control the use of specific additives in drinking water, EPA has provided technical assistance to States and public water systems on the use of additives through the issuance of advisory opinions on the acceptability of many additive products. EPA has provided this technical assistance pursuant to its discretionary authority in section 1442(b)(1) to "collect and make available information pertaining to research, investigations and demonstrations with respect to \*25587 providing a dependable safe supply of drinking water together with appropriate recommendations in connection therewith." EPA has additional authorities under the Toxic Substances Control Act (TSCA) (15 U.S.C. 2601 et seq.) and the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) (7 U.S.C. 136 et seq.) that could be used to control additives in drinking water. TSCA authorizes EPA to regulate a new chemical substance before it is manufactured or any existing chemical substance before it is manufactured or processed for a use that EPA has determined to be a "significant new use." Although an additive product might come within the jurisdiction of TSCA, EPA has never invoked this authority. EPA has used its authority under FIFRA to control the use of pesticides, disinfectants, and certain other additives. For a more complete discussion of these authorities, see the MOU. 44 FR 42776.

In 1980, EPA declared a moratorium on the issuance of new advisory opinions on additives pending a review of past advisory opinions and the establishment of uniform test protocols and decision criteria. However, between 1980 and 1984, EPA continued to issue advisory opinions in cases where the new additive products were virtually identical to products previously reviewed. Resource constraints and the need to implement mandatory provisions of the SDWA precluded the Agency from implementing the comprehensive program originally envisioned for the issuance of additives advisory opinions. Thus, the Agency was not able to review the technical data supporting previous submissions (approximately 2,300 products from 525 manufacturers) nor was it able to develop test protocols or decision criteria for the consistent evaluation of new products. The result has been long delays in processing manufacturer petitions, inability to review and accept completely new products, and acceptance of products simply because they were virtually identical to older products. Hence, few products have been thoroughly evaluated for the safety of their formulations based on the latest scientific information.

Recognizing the need for continuing technical assistance in evaluating additive products and for providing advice to States and public water systems on the toxicological aspects of additive products, the Agency proposed to terminate its attempts to institute a formal advisory program, and to solicit proposals from nongovernmental, nonprofit organizations to establish such a program in the private sector. The Agency believed that the proposal to assist in the establishment of a private-sector program was consistent with, and would best serve the goals of, the SDWA.

On May 17, 1984, EPA formally announced its intention to transfer the program to the private sector, which would function as to many other voluntary product-

standard programs. 49 FR 21004. . This was accomplished by requesting proposals from qualified organizations or consortia of organizations for the competitive award of a cooperative agreement designed to provide incentive for the establishment of a private-sector program. The 1984 notice stated that:

- EPA expected the activity to be self-supporting.
- EPA would maintain an active interest in the development of the program, without assuming responsibility for or directing its approach.
- EPA would continue to establish regulations under the SDWA, FIFRA, and/or TSCA, as needed, for chemicals in treated, distributed drinking water that may originate as additives.
- Establishment of such a program would be consistent with the Administration's initiatives in the area of regulatory reform and offered an opportunity for an innovative alternative to regulation.

The May 1984 notice requested public comments on the proposal and solicited applications from qualified nongovernmental, nonprofit organizations for partial funding of the developmental phase of the program under a cooperative agreement. The response to the solicitation for comments indicated strong public support for the proposed approach. EPA received 106 public comments on the proposal. All but six supported this "third-party" approach. However, despite the Agency's open competition, EPA received only one application for financial assistance. The applicant was a consortium, led by the National Sanitation Foundation, which included the American Water Works Association Research Foundation, the Conference of State Health and Environmental Managers, and the Association of State Drinking Water Administrators. This single proposal met all of the basic criteria articulated in the May 1984 notice. Furthermore, EPA believed that the single applicant was very likely to succeed, because it represented an organization experienced in private-sector consensus standard-setting, State regulators, and water utilities.

EPA awarded the cooperative agreement to the NSF consortium on September 17, 1985, and committed funding of \$185,000 to NSF over a three-year period. The non-Federal (consortium and participating industry) contribution during the first three years of the program was projected to be approximately \$1.4 million.

The NSF program has the following major objectives:

- To develop systematic, consistent, and comprehensive voluntary consensus standards for public health safety evaluation of all products (previously EPA-accepted as well as new) intended for use in drinking water systems.
- To obtain broad-based participation in the standard-setting program from industry, States, and utilities.
- To provide for regular periodic review, update, and revision of the standards.
- To undertake needed research, testing, evaluation, and inspections and to provide the followup necessary to maintain the program.

- To establish a separate program for testing, evaluation, certification, and listing of additive products.
- To widely disseminate information about the program, and to make information about conforming products available to users.
- To maintain the confidentiality of all proprietary information.
- To fully establish the third-party program on a self-supporting basis.

NSF's established standard-setting process utilizes a tiered structure. Each standard is drafted by a task group and then presented to a Joint Committee, which includes 12 industry, 12 user, and 12 regulatory members. Following successful Joint Committee balloting, standards are reviewed by the Council of Public Health Consultants, which is a high level advisory group consisting of technical and policy experts from regulatory agencies and academia.

NSF has established task groups to develop standards for the product categories listed below. Each task group includes a member representing the regulatory agencies and a member representing the utilities. All manufacturers expressing interest in a particular product task group may participate as members of that group. Therefore, task group membership is predominately manufacturers. In addition, a group of health effects consultants is addressing the toxicological and risk considerations for various product categories. NSF's role in the standard-setting process is administrative, that is, to bring together experts from government, industry, \*25588 utilities, users, and other relevant groups so that a standard which reflects a consensus of these interests can be developed. In addition, NSF staff provide technical leadership and laboratory support. Product categories and corresponding task groups are:

- Protective Materials.
- Chemicals for Corrosion and Scale Control, Softening, Precipitation, Sequestering, and pH Adjustment.
- Coagulation and Flocculation Chemicals.
- Miscellaneous Treatment Chemicals.
- Joining and Sealing materials.
- Process Media.
- Pipes and Related Products.
- Disinfection and Oxidation Chemicals.
- Mechanical Devices.

All of the task groups have made satisfactory progress during the term of the cooperative agreement. In addition, the health effects consultants have endorsed



the bases of the standards. Standards have been drafted for all product categories, and final standards were published and implemented as follows:

*Standard 60, December 1987*

- Chemicals for Corrosion and Scale Control, Softening, Precipitation, Sequestering, and pH Adjustment.
- Disinfection and Oxidation Chemicals.
- Miscellaneous Treatment Chemicals (selected).

*Standard 61, June 1988*

- Process Media.

Development of the remaining standards is on schedule, and publication and implementation are expected on the following schedule:

*Standards 60 and 61, expected October 1988*

- Protective Materials.
- Coagulation and Flocculation Chemicals.
- Miscellaneous Treatment Chemicals (additional).
- Joining and Sealing Materials.
- Pipes and Related Products.
- Mechanical Devices.

*P.P.e standards  
not yet developed!*

EPA believes that the NSF program is successfully pursuing all of its objectives. Furthermore, the program is strongly supported by user and regulatory sectors. AWWARF, COSHEM, ASDWA, the Great Lakes Upper Mississippi River Board, the American Water Works Association (AWWA) (including the Utilities and Standards Councils and the Regulatory Agencies Division), and the Association of Metropolitan Water Agencies, among others, have voiced strong support for the third-party program. The AWWA recently joined the NSF-led consortium and urged EPA to support national uniform accreditation of certifying entities for additives products. To date, more than 60 manufacturers are full participants in the standard-setting program.

The cooperative agreement between EPA and the consortium requires NSF to establish both a standard-setting program and a service for testing, certification, and listing. These are completely separate activities. EPA's intent is to support the development of a widely accepted uniform standard for each category of products while encouraging the development of competing sources for testing, certification, and listing. The cooperative agreement assures that at least one sound and reliable product-evaluation service will be available to manufacturers, i.e., the consortium. However, the consortium's standards will allow for entities other than NSF to be evaluators of products.

EPA recognizes the authority and responsibility of the individual States to determine the acceptability of drinking water additives. Hence, it is up to the States and utilities to determine the suitability of any "third-party" certification. AWWARF will maintain a directory of products approved by all organizations claiming to conduct evaluations under Standards 60 and 61. However, AWWARF will not judge the competence or reliability of these organizations.

## II. Announcement of Phase-Down of EPA's Additives Program

During the developmental phase of the NSF consortium's program, EPA has continued to review products and process requests for advisory opinions on a limited basis. The May 1984 notice stated that, "EPA does not intend to develop further interim administrative procedures, testing protocols or decision criteria for future evaluation of additive products. The use of existing informal criteria will continue until a third-party or alternative program is operational \* \* \*. EPA may not be able to process all requests for opinions on additive products before the establishment of a cooperative agreement with a third party. The large volume of currently pending requests makes it unlikely that additional requests will be completely processed by that date." Likewise, EPA, in its acknowledgment letters to manufacturers requesting opinions on new products, explains that the Agency is, "\* \* \* making a concerted effort to process petitions as quickly as possible. However, EPA may not be able to process your request for an opinion on an additive product before the establishment of an alternative program as described in the Federal Register, Vol. 49, No. 97, 21003-8, May 17, 1984." Product reviews and issuance of advisory opinions have been limited to:

- Products composed entirely of other products which EPA had previously determined to be acceptable;
- Products composed entirely of ingredients which have been determined to be acceptable by EPA or the FDA, or other Federal agencies, for addition to potable water or aqueous foods;
- Products composed entirely of ingredients listed in the "Water Chemicals Codex," National Academy of Sciences, November 1982, and in the "Water Chemicals Codex: Supplementary Recommendations for Direct Additives," National Academy of Sciences, 1984;
- Certain other products of particular interest to EPA or to other Federal agencies; and
- Products which, if effectively excluded from the marketplace by lack of approval, might jeopardize public health or safety.

Continued processing of petitions during the development of the private-sector program minimized disruption of the marketplace from the viewpoint of manufacturers whose business depended in part on EPA acceptance of products, users who required water treatment products for the production of safe drinking water, and State officials who rely on the advice of EPA.

EPA believes that NSF is moving expeditiously and on schedule toward the full

establishment of a third-party program covering products intended for use in drinking water systems. Priorities for standards development and implementation of a testing, certification, and listing program for various product categories have been based upon need, interest, complexity, and availability of information for developing standards. Direct drinking water additives were assigned high priority for the following reasons: (1) Use of direct additives is widespread in drinking water systems, so there are large population exposures to these chemicals; (2) as direct additives to drinking water, they present greater potential for water contamination than indirect mechanisms (e.g., migration from protective paints in pipes and storage tanks); and (3) the National Academy of Sciences' Water Chemicals Codex provided a good starting point for development of standards.

**\*25589** As originally planned, EPA is beginning to phase out the Agency's additives evaluation program. Thus, EPA will not accept new petitions or requests for advisory options after the date of this notice. While EPA will continue to process requests which are pending and those received on or before July 7, 1988, petition evaluations not completed by October 4, 1988, will be returned to the submitter. After that date, EPA will no longer evaluate additive products.

Petitions which are completely evaluated by October 5, 1988, will be added to the quarterly list of acceptable products published shortly after that date. That quarterly list will be the last such list issued by EPA. On April 7, 1990, EPA will withdraw its list of acceptable products, and the list and the advisories on these additives will expire. This means that: (1) The various lists published by EPA under the titles Report on Acceptable Drinking Water Additives, Report on Coagulant Aids for Water Treatment, Report on Concrete Coatings/Admixture for Water Treatment, Report on Detergents, Sanitizers and Joint Lubricants for Water Treatment, Report on Evaporative Suppressants for Water Treatment, Report on Liners/Grouts/Hoses and Tubings for Water Treatment, Report on Miscellaneous Chemicals for Water Treatment, Report on Protective Paints/Coatings for Water Treatment, and any and all other lists of drinking water products issued by EPA or its predecessor agencies regarding drinking water additives will be invalid after April 7, 1990; and (2) advisory opinions on drinking water additives issued by EPA and predecessor agencies will be invalid after that date.

EPA believes that, while in the past every effort has been made to provide the best possible evaluations, all products should be evaluated against carefully developed and considered nationally uniform standards. Many of the currently listed products were evaluated and accepted up to 20 years ago and have not been reevaluated since that time. Numerous products have been accepted because they were virtually identical to or were repackagings of older products. The result is that few products have been completely evaluated for the safety of their original or current formulations vis-a-vis the latest toxicological, chemical, and engineering information. A uniform evaluation of all products, old and new, will result in consistent quality of products, and will assure fair and equitable treatment to all manufacturers and distributors.

Henceforth, parties desiring to have existing or new products evaluated against the NSF standards should contact NSF or other organizations offering such evaluations. To contact NSF about the drinking water additives program write to: David Gregorka, National Sanitation Foundation, P.O. Box 1468, Ann Arbor, MI 48106, or call (313) 769-8010. Information on alternatives to NSF evaluation may be

obtained by contacting State regulatory agencies or the AWWA, Technical and Professional Department, 6666 Quincy Avenue, Denver Co, 80235, or call (303) 794-7711, which is addressing certifier accreditation.

EPA believes that the 21 months between today and the expiration date of EPA's last list is sufficient time for manufacturers to submit their products to NSF or other certification entities for evaluation. The first NSF list will be published prior to April 7, 1990, thereby preventing any disruption in the marketplace. Furthermore, NSF had indicated that it will consider current EPA and other regulatory evaluations when evaluating products in order to ensure a smooth transition. States may choose to rely on the last EPA quarterly list of products until their individual programs for accepting private-sector certification are fully implemented.

Parties desiring to market drinking water additive products are reminded that the individual States have the authority to regulate the sale and/or use of specific products as they see fit. Thus, reliance upon a particular standard or organization to certify that a product complies with a particular standard must be acceptable to the State in which the supplier wishes to do business.

Discontinuation of the additives program at EPA does not relieve the Agency of its statutory responsibilities. If contamination resulting from third-party sanctioned products occurs or seems likely, EPA will address that issue with appropriate drinking water regulations or other actions authorized under the SDWA. EPA is a permanent member of the NSF program Steering Committee, and senior EPA staff and management will continue to participate in this and other programs designed to assure that high-quality products are employed in the treatment of public drinking water. Also, the Agency will continue to sponsor research on contaminants introduced in public water supplies during water treatment, storage, and distribution.

### III. Comments

Although this notice does not include a proposed or final regulation, EPA welcomes comments and suggestions that would assist the Agency in implementing the additives program phasedown. Please address all comments and suggestions to: Mr. Arthur H. Perler, Chief, Science and Technology Branch, Office of Drinking Water (WH-550D), U.S. Environmental Protection Agency, 401 M Street, SW., Washington, DC 20460.

Date: June 16, 1988.

William Whittington,

Acting Assistant Administrator for Water.

[FR Doc. 88-15232 Filed 7-6-88; 8:45 am]

BILLING CODE 6560-50-M

53 FR 25586-01, 1988 WL 260340 (F.R.)

END OF DOCUMENT



CPVC 2006

RG.216  
Doc.216

**From:** Jim Aguila [jaguila@arb.ca.gov]  
**Sent:** Thursday, March 30, 2006 1:47 PM  
**To:** CPVC 2006  
**Cc:** Carla Takemoto; Marline Hicks  
**Subject:** [Fwd: [Fwd: Toxic air contaminants]]

**Attachments:** [Fwd: Toxic air contaminants]



[Fwd: Toxic air  
contaminates]

Hi Robin- I am the manager of the group that maintains the toxic air contaminant (TAC) list which you referenced from our website. We are aware of USEPA's delisting of MEK and currently do not have plans to remove it from the California TAC list. However, we will further evaluate MEK as part of our ongoing TAC list update process, which we hope to complete by the end of the year.

Thank you for your inquiry. If you have questions, please call me at (916) 322-8283.

Jim Aguila, mgr.  
Substance Evaluation Section  
SSD/AQMB  
California Air Resources Board

## CPVC 2006

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**From:** Brown, Jeremy [Brown@nsf.org]  
**Sent:** Thursday, March 16, 2006 7:24 AM  
**To:** CPVC 2006  
**Subject:** RE: CPVC cements

Robin,

You will find most of the Solvent Cements listed to NSF-14. Those solvent cements that also meet NSF-61 will have a footnote in the NSF-14 listing indicating such. Search under <http://www.nsf.org/Certified/Plumbing/> and you will find a couple more one steps and more low VOC products. For those companies listed under NSF-14 with a NSF-61 footnote, they have a choice for whether their products will also be additionally listed in the NSF-61 listings. Let me know if you have further questions.

Regards,

Jeremy Brown  
Codes & Regulatory Manager  
NSF International  
phone 1-734-769-5196  
fax 1-734-827-7129

-----Original Message-----

**From:** CPVC 2006 [mailto:CPVC2006@hcd.ca.gov]  
**Sent:** Tuesday, March 14, 2006 7:22 PM  
**To:** Jeremy Brown  
**Subject:** CPVC cements

Jeremy,

I was just looking on your website and tried to search for NSF 61 certified low-VOC, one-step cements.

I could only find one "one-step low VOC" CPVC cement. It is listed under the IPS Corp, Gardena, CA facility.

It appears that this company (IPS) is also the only one who is certified to make low VOC (not limited to one-step) cements.

Is there really only one certified brand that is one-step & low-VOC and one manufacturer who is certified to make low-VOC CPVC cement?

Thank you,  
Robin

**Robin Gilb, Staff Counsel**  
Department of Housing and Community Development

3/16/2006

## CPVC 2006

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**From:** Brown, Jeremy [Brown@nsf.org]  
**Sent:** Monday, February 27, 2006 10:52 AM  
**To:** CPVC 2006  
**Subject:** RE: Normative references

Robin,

Yes, products certified to NSF-14 that have material, design and construction requirements applicable to the reference standards, the product is evaluated and certified to the applicable reference standard(s).

Regards,

Jeremy Brown  
Codes & Regulatory Manager  
NSF International  
phone 1-734-769-5196  
fax 1-734-827-7129

-----Original Message-----

**From:** CPVC 2006 [mailto:CPVC2006@hcd.ca.gov]  
**Sent:** Monday, February 27, 2006 1:33 PM  
**To:** Jeremy Brown  
**Subject:** Normative references

Standards 14 & 61 refer to "normative references" and list several relating to CPVC. For example, the following are listed in NSF 14:

ASTM D 2846/D 2846M-99  
Standard Specification for CPVC Plastic Hot- and Cold - Water Distribution Systems.

ASTM F 437-99  
Standard specification for threaded CPVC plastic pipe fittings, schedule 80

ASTM F 438-02e1  
Specification for socket – type CPVC plastic pipe fittings, schedule 40

ASTM F 439 -02e1  
Specification for socket – type CPVC plastic pipe fittings, schedule 80

ASTM F 441/F 44102  
Specification for CPVC plastic pipe fittings, schedules 40 and 80

ASTM F 442/F 442M-99  
Standard specification for CPVC plastic pipe (SDR-PR)

ASTM F 493-97  
Standard specification for solvent cements for CPVC plastic pipe and fittings.

CSA B137.6-05



CPVC pipe, tubing and fittings for hot and cold water distribution systems

ASTM D 4396-99ae1

Standard specification for rigid PVC and CPVC compounds for plastic pipe and fittings used in nonpressure applications.

What is meant by "normative references"? Are NSF/ANSI 14 certified products required to meet these standards as well as the requirements listed in 14?

Thank you

**Robin Gilb, Staff Counsel**

Department of Housing and Community Development

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Sacramento, CA 95814

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## CPVC 2006

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**From:** Robin Gilb  
**Sent:** Thursday, March 02, 2006 3:53 PM  
**To:** CPVC 2006  
**Subject:** FW: contact info - GAMA program

---

**From:** Book, Steven (DHS) [mailto:sbook@dhs.ca.gov]  
**Sent:** Tuesday, February 21, 2006 11:37 AM  
**To:** Robin Gilb  
**Subject:** RE: contact info - GAMA program

Robin:

The Water Board's GAMA Program (Groundwater Ambient Monitoring and Assessment) might have some data of value to you in your EIR activities. It's here: <http://www.waterboards.ca.gov/gama/>

--Steve Book

-----Original Message-----

**From:** Robin Gilb [mailto:rgilb@hcd.ca.gov]  
**Sent:** Tuesday, February 21, 2006 11:11 AM  
**To:** Book, Steven (DHS)  
**Subject:** contact info

Thank you for your help!

**Robin Gilb, Staff Counsel**  
Department of Housing and Community Development  
rgilb@hcd.ca.gov  
Phone: (916) 324-5817  
Fax: (916) 323-2815

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**Robin Gilb**

---

**From:** Springborn, Robert (DHS-DDWEM) [RSpringb@dhs.ca.gov]  
**Sent:** Monday, February 27, 2006 8:21 AM  
**To:** Robin Gilb  
**Subject:** contact info at HCD for CD

Hi Robin,

I've a water quality data CD to send to you. Please write back with an address.

thanks     rob

-----Original Message-----

**From:** Meeks, Anthony (DHS-DDWEM)  
**Sent:** Monday, February 27, 2006 8:10 AM  
**To:** Springborn, Robert (DHS-DDWEM)  
**Subject:** FW: contact info at HCD for CD

Robert,

Please send the CD to Robin Gilb at the address below; please tell me when it has been placed in the mail.

Please sign me out, I need to take care of some business today.

Anthony

---

**From:** Book, Steven (DHS)  
**Sent:** Fri 2/24/2006 2:54 PM  
**To:** Meeks, Anthony (DHS-DDWEM)  
**Subject:** FW: contact info at HCD for CD

Anthony:

Did you get a chance to send a CD to Ms. Gilb?

Thanks.

--Steve

-----Original Message-----

**From:** Book, Steven (DHS)  
**Sent:** Tuesday, February 21, 2006 11:16 AM  
**To:** Meeks, Anthony (DHS-DDWEM)  
**Cc:** 'rgilb@hcd.ca.gov'; Collins, Paul (DHS-DDWEM)  
**Subject:** FW: contact info at HCD for CD

3/17/2006

2 - 0004

CPVC 2006

From: Calvin Willhite [CWillhit@dtsc.ca.gov]  
Sent: Monday, March 13, 2006 3:05 PM  
Subject: CPVC 2006  
Re: CPVC EIR scope comment (SCH 2006012044)

Good Afternoon Ms. Gilb,

As noted in the review memorandum, any solvents used in PVC/CPVC associated with any such installation of CPVC products are regulated under both Federal and State drinking water Maximum Contaminant Limits. That is the extent of State enforcement capability to my knowledge. This department has no jurisdiction or authority as regards either construction materials, industry practice or occupational exposures.

The only possible Cal/EPA exception might concern the Office of Environmental Health Hazard Assessment and Proposition 65 warning requirements should any of the products involve listed substances. You might contact the OEHHA, but in general the employee exposure to solvents used in CPVC installation are regulated by Cal/OSHA and the concentrations of any residual vinyl chloride monomer or other substances in tap water are regulated by the Drinking Water Branch of the Department of Health Services. Please keep in mind that the concentrations of any solvent or other materials used or found during installation decline rapidly over time and the concentrations are not static. Given the very small quantity of the installation materials used in relation to the relative massive quantities of water used in a typical home and the rapid decline in solvent concentrations in the field, the concentrations of any regulated materials will likely be less than the analytical limits of detection in VERY short order. To obtain an authoritative response, the DHS Office of Drinking Water is the place to check.

As an aside, my house (built by Shea Homes) in Marin County (constructed in 2003) has this plastic plumbing for tap water supply. I trust this answers your inquiry. Calvin C. Willhite

>>> "CPVC 2006" <CPVC2006@hcd.ca.gov> 3/13/2006 10:37 AM >>>  
Re: CPVC EIR scope comment (SCH 2006012044)

Dr. Willhite:

Thank you for the comments, dated 3/2/06, on the above referenced EIR. The comments seem to be for a project based solely in Butte County, however, the EIR is for statewide application of CPVC residential plumbing.

Would your department like to retain your position in light of this expansion of the project over what was contemplated by your comments? The only comment that seems to be restricted to a specific county is in the conclusion where you reference §64444 of Title 22 CCR relating to "service areas with less than 200 connections - the applicable County."

One of the specific issues we were hoping your agency would address is the concern that expanding the use of CPVC throughout the state would result in an increase in the discharge of chemical contaminants from the newly installed pipe (leachates from the new pipe and cements). This is thought to be a cumulative impact with potential adverse impacts. Since the household discharge water frequently ends up in streams, rivers or the ocean, after POTW treatment, your agency may have relevant comments to make even if household discharge is not in your jurisdiction.



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### Airborne contaminants

Public hearing: September 15, 2005  
Date adopted: April 20, 2006  
Filed with Secretary of State: June 6, 2006  
Effective date: July 6, 2006

## Occupational Safety and Health Standards Board (OSHSB)

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General Industry Safety Orders  
Chapter 4, subchapter 7, article 107  
Section 5155

### Airborne contaminants

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**OCCUPATIONAL SAFETY  
AND HEALTH STANDARDS BOARD**

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Attachment No. 2

**INITIAL STATEMENT OF REASONS****CALIFORNIA CODE OF REGULATIONS**

Title 8: Chapter 4, Subchapter 7, Article 107, Section 5155  
of the General Industry Safety Orders

**Airborne Contaminants****SUMMARY**

Pursuant to California Labor Code Section 142.3, the Occupational Safety and Health Standards Board (Standards Board) may adopt, amend, or repeal occupational safety and health standards or orders. Section 142.3 permits the Board to prescribe, where appropriate, suitable protective equipment and control or technological procedures to be used in connection with occupational hazards and provide for monitoring or measuring employee exposure for their protection. California Labor Code Section 144.6 requires that the Standards Board, when dealing with standards for toxic materials and harmful physical agents, adopt standards which most adequately assure, to the extent feasible, that no employee suffer material impairment of health or functional capacity even if such employee has regular exposure to the hazard for the period of one's working lifetime. This section also requires that the Standards Board base standards on research, demonstrations, experiments and other information as may be appropriate. Labor Code Section 144.6 also lists other considerations such as the latest scientific literature, the reasonableness of the standards, and the experience gained in this and other health and safety laws.

Existing Section 5155 establishes minimum requirements for controlling employee exposure to specific airborne contaminants. This section specifies several types of airborne exposure limits, requirements for control of skin and eye contact, workplace environmental monitoring through measurement or calculation, and medical surveillance requirements. On an ongoing basis with the assistance of an advisory committee, the Division develops proposals to amend these airborne exposure limits known as Permissible Exposure Limits (PELs). This ongoing review is necessary to take into account changes in the information available to assess the effects of exposures to airborne substances that can be present in the workplace.

**SPECIFIC PURPOSE AND FACTUAL BASIS OF THE PROPOSED ACTION**

In accordance with Labor Code Section 144.6, the purpose of this amendment to Section 5155 is to regulate employee exposure to toxic materials such that, to the extent feasible, the health or functional capacity of the employee is not materially impaired. This proposal was developed by

the Division of Occupational Safety and Health (Division) pursuant to the Division's independent mandate to maintain surveillance and propose standards to the Standards Board in accordance with Labor Code Section 147.1. The Division has developed and presented similar proposals to the Standards Board in the past, normally at approximately three-year intervals. The Division relies in part on changes made to the American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Values (TLVs) to indicate substances to be considered for change. The development of this proposal is consistent with past practice and uses the accumulated changes of the ACGIH for the years 1997, 1998, 1999, 2000, and 2001. The ACGIH changes to TLVs are used to produce the base list for consideration for several reasons. The ACGIH TLVs are the most comprehensive single source of exposure limits available, the ACGIH TLVs are substantiated by available documentation, and there is ongoing review of the TLVs by the ACGIH with annual revision.

The Division, in developing the current and past proposals, has convened advisory committees to consider and make recommendations on the substances in the base list. The Airborne Contaminants Advisory Committee (Committee), which considered substances for development of this proposal, met between May 2001 and January 2004. The Committee independently evaluated the changes made to TLVs using the ACGIH documentation, presentations and additional documentation provided by interested parties, documents referred to in the ACGIH documentation, and other documents provided by the members of the Committee.

In many cases, the Committee's recommendations agreed with the rationale and limits set by the ACGIH. In some cases, the Committee made recommendations not in agreement with the ACGIH limits. In other cases, the Committee used a different basis than the one used by the ACGIH. The Committee's recommendations were based on the consensus opinion among the members. After the Committee made its recommendations, the Division held additional public advisory meetings on those substances where the Committee made recommendations that differed from the TLV limits. The purpose of these meetings was to solicit additional information on the impacts of implementing these generally lower levels and their scientific basis. In some cases the levels recommended by the committee were changed based on information received in this additional review.

The following is a discussion of the specific changes to Table AC-1 in the order that they occur in the proposal. The ACGIH documents, minutes of the Advisory Committee meetings, other documents and reasons listed below form the factual basis for this proposal.

The Permissible Exposure Limit (PEL) for Acetone is proposed to be lowered from 750 parts per million (ppm) to 500 ppm (1780 mg/M<sup>3</sup> and 1200 mg/M<sup>3</sup>, respectively). The current Short Term Exposure Limit (STEL) is also proposed to be lowered from 1000 ppm to 750 ppm (2400 mg/M<sup>3</sup> and 1780 mg/M<sup>3</sup>, respectively). This limit was adopted by the ACGIH in 1997 and was also observed in the Nelson, et al. study. The Committee recommended lower limits of 250 ppm and 500 ppm STEL based on irritation observed in the Nelson, et al. study. However, at the March 30, 2004, advisory meeting, John Bankston of the American Chemistry Council Acetone Panel stated that the Nelson, et al. study used naive test subjects making it difficult for the study to find the true level for inducing irritation. More recent studies with better study design did not



confirm the Nelson results and showed a higher irritation threshold. As a result, it is proposed to amend the limits to be consistent with the ACGIH. The proposed change is necessary to protect employees from these irritant effects.

The time-weighted average PEL for Beryllium, and beryllium compounds as Be is proposed to be lowered from 0.002 mg/M<sup>3</sup> (2 ug/M<sup>3</sup>) to 0.2 ug/M<sup>3</sup> as total dust analyzed for beryllium. A PEL of 0.1 ug/M<sup>3</sup> was originally recommended by the Committee that differs from both the current ACGIH TLV of 2 ug/M<sup>3</sup> as total dust and the 2001 proposed change to the ACGIH TLV of 0.2 ug/M<sup>3</sup> as an inhalable fraction. In 2005, the ACGIH draft TLV documentation was amended to support a new Notice of Intended Change (NIC) for the TLV to 0.02 ug/M<sup>3</sup>. The amended draft documentation and NIC lends support to the proposed lowering of the PEL for beryllium from 2 to 0.2 ug/M<sup>3</sup>. Because the amended NIC and draft TLV documentation for beryllium was only recently released during the preparation of the present rulemaking proposal, the Division plans to include it in the next air contaminants advisory committee process to determine if further changes to the PEL for beryllium are necessary. The Airborne Contaminants Advisory Committee based its recommendation primarily on a 1996 study by Kreiss et al., which studied the levels of beryllium disease among 136 workers at a beryllium ceramics plant. The study found that 5.9% of employees were sensitized to beryllium as indicated by the beryllium lymphocyte proliferation blood test, and that 4.4% of employees had granulomatus disease on transbronchial lung biopsy. This plant took 4,133 breathing zone samples with a median value of 0.3 ug/M<sup>3</sup>. The Committee also referred to a study of community cases in the vicinity of beryllium production plant, Eisenbud 1949, where beryllium disease had been observed with 24-hour exposures estimated near 0.01 ug/M<sup>3</sup>. During the March 30, 2004, advisory meeting, several differing opinions were raised for the Committee's consideration: the use of subclinical chronic beryllium disease as an end point, problems with feasibility of control at 0.1ug, Eisenbud study data errors, and the ACGIH use of an "inhalable" sampler. In response to these comments, the originally proposed PEL of 0.1 ug/M<sup>3</sup> has been modified to 0.2 ug/M<sup>3</sup> sampled as total dust. The proposed limit is necessary to prevent sensitization and beryllium disease. The proposed revised PEL-TWA renders duplicative the existing PEL-STEEL (30-minute), because complying with the 8-hour TWA of 0.2 ug/M<sup>3</sup> necessarily results in compliance with the existing 30-minute PEL-STEEL. The text of existing footnote (p) associated with the PEL-STEEL for beryllium is proposed to be deleted and the footnote reserved for possible future use.

A new PEL for Bis (Dimethylaminoethyl) ether (DMAEE) is proposed at 0.05 ppm (0.328 mg/M<sup>3</sup>) and a STEEL of 0.15 ppm (0.983 mg/M<sup>3</sup>). This limit was recommended by the Committee and is the same as the ACGIH TLV adopted in 2000. The proposed limit is based on a 14-week inhalation study of rats showing signs of eye and respiratory tract irritation at 0.23 ppm, with periodic swelling at 0.23 ppm. A skin notation is also proposed based on severe effects on the skin and eyes of rabbits and kidney effects in rabbits with dermal application. The proposed limit is supported by the ACGIH document for bis (dimethylaminoethyl) ether. The proposed change is necessary to protect employees from these irritant effects.

The PEL for 2-Butoxyethanol is proposed to be lowered from 25 ppm (120 mg/M<sup>3</sup>) to 20 ppm (80 mg/M<sup>3</sup>) based on eye and nose irritation in human volunteer exposures at 200 ppm, Carpenter et al. Two human volunteers exposed to 113 ppm 2-butoxyethanol for four hours

experienced nasal and ocular irritation, a disagreeable metallic taste, and a slight increase in nasal mucous discharge. Four to six hours later, one of these men reported that he felt as though he had "smoked too many cigarettes;" although none had been used. The important finding here is for the 113 ppm four hour human exposure. The Committee considered the hemolysis seen in some animal species, but agreed with the conclusion drawn by the ACGIH in its documentation for 2-Butoxyethanol, that hemolysis was not a significant consideration for human exposure. The Committee originally chose 10 ppm because it wanted to provide a margin of safety of 20 that would produce no effects, as opposed to the effects seen at 200 and 113 by Carpenter et al. This differed from the 20 ppm TLV adopted by the ACGIH in 1999. Richard Corley of the Center for Biological Monitoring & Modeling speaking on behalf of the American Chemistry Council Ethylene and Propylene Glycol Ethers Panel offered a differing opinion on the Carpenter study at the March 30, 2004, advisory meeting and recommended a level of 20 ppm consistent with the ACGIH by noting that newer studies did not show irritation at levels higher than in these two studies. The Division has chosen to accept the suggestion of Mr. Corley and propose an amended PEL of 20 ppm consistent with the current ACGIH TLV. The proposed limit is necessary to protect employees from the eye and nose irritation.

For Coal Tar Pitch Volatiles the table entry and associated footnote is proposed to be amended to make it at least as effective as its federal OSHA counterpart. It is proposed to modify the language of the existing entry for "coal tar pitch volatiles" in Table AC-1 of Section 5155 to the extent of eliminating the Chemical Abstracts Registry Number that refers only to residue from the high temperature distillation of coal tar. This change is necessary to clarify that the standard applies to airborne mixtures of chemicals from a number of sources. It is proposed to modify existing footnote "i" in Table AC-1 of Section 5155 so that it is substantively identical to 29 CFR 1910.1002 in clarifying what substances and processes are included in the term "coal tar pitch volatiles." The amendment is necessary to make the language of the standard at least as effective as the federal OSHA counterpart by including reference to source materials other than coal tar, consistent with the federal OSHA standard at 29 CFR 1910.1002.

The PEL for Crotonaldehyde is proposed to be lowered from 2 ppm time-weighted average to 0.3 ppm ceiling with a Skin designation based on irritation effects seen in workers at 1 ppm. The skin designation is based on dermal LD50 values. The proposed limit was recommended by the Committee and is the same as the TLV adopted by the ACGIH in 1999. The proposed limit is supported by the ACGIH document for crotonaldehyde. The proposed change is necessary to protect employees from these irritant effects.

The PEL for Epichlorohydrin is proposed to be lowered from 2 ppm (7.6 mg/M<sup>3</sup>) to 0.05 ppm (0.19 mg/M<sup>3</sup>) based on reproductive toxicity at levels above 5 ppm seen in laboratory animals. The proposed limit was recommended by the Committee and differs from the 0.5 ppm TLV adopted by the ACGIH in 1997. The Committee noted that the International Agency for Research on Cancer (IARC) considers this substance a probable human carcinogen, and that the reproductive and respiratory effects seen had been confirmed in multiple studies cited in the ACGIH document. The Committee members thought that there was an insufficient margin of safety between the reproductive effects seen in animals and the ACGIH threshold limit value and recommended the 0.05 ppm limit on the basis that it would reduce the risk of these reproductive

outcomes. There were comments received from Susan Ripple at the March 30, 2004, advisory meeting regarding sampling and analytical methods for epichlorohydrin. Ms. Ripple stated that there were two methods with limits of detection at 0.01 ppm for this substance. There were no comments received regarding the scientific basis for the proposed limit. The proposed change is necessary to control reproductive and respiratory effects and the possibility of carcinogenic effects.

The PEL for Glutaraldehyde is proposed to be lowered from a ceiling limit of 0.2 ppm (0.82 mg/M<sup>3</sup>) to a ceiling limit of 0.05 ppm (0.2 mg/M<sup>3</sup>), the same as the ACGIH TLV since 1997. The documentation of the TLV notes that it may not protect susceptible workers from sensitization or an allergic reaction. The Committee initially proposed a level of 0.015 ppm. However, in a series of 3 supplemental advisory meetings held in 2004, the 0.05 ppm level based on ACGIH documentation was recommended and considered to be feasible among a wide range of employers using engineering controls based upon statements by users of glutaraldehyde. The 2004 advisory group further recommended an informational footnote on hazards and control of exposures to glutaraldehyde be added to Table AC-1 in recognition of the potential risk of sensitization and asthma remaining to employees at the proposed PEL. The 2004 advisory group also recommended users of glutaraldehyde be given time to achieve compliance with the proposed ceiling limit of 0.05 ppm by means of engineering controls. It is therefore further proposed to provide a 2-year period during which the PEL would be 0.05 ppm as an 8-hour time-weighted average rather than a ceiling limit. The necessity of adding these 2 footnotes and proposing a 0.05 ppm ceiling limit was further supported by the 2004 letters from Thomas Tremble and Susan Ripple. The proposed change is necessary to reduce the risk of occupational asthma posed by workplace exposure to glutaraldehyde.

The PEL for Hexachlorobenzene is proposed to be lowered from 0.025 mg/M<sup>3</sup> to 0.002 mg/M<sup>3</sup> based on hepatic and neurological effects. Several studies have demonstrated excesses of hepatic tumors in different species. The proposed limit is recommended by the Committee and is the same as the TLV adopted by the ACGIH in 1999. The proposed limit is supported by the ACGIH document for hexachlorobenzene. The proposed change is necessary to protect employees from these hepatic and neurological effects.

The PEL for n-Hexane is proposed to be changed by adding a Skin designation. A skin designation is proposed based on observations of human peripheral neuropathy after contact with n-hexane. The metabolite of n-hexane, methyl n-butyl ketone has also shown this effect. The proposed limit is recommended by the Committee and is the same as the TLV adopted by the ACGIH in 1998. The proposed "Skin" designation is supported by the ACGIH document for n-hexane. The proposed change is necessary to protect employees from peripheral neuropathy.

A new PEL for 1-Hexene is proposed at 50 ppm (180 mg/M<sup>3</sup>) based on an estimated No Observed Adverse Effect Level (NOAEL) of 1000 ppm in rats for body weight loss. The proposed limit is recommended by the Committee and is the same as the TLV adopted by the ACGIH in 1998. The proposed limit is supported by the ACGIH document for 1-hexene. The proposed change is necessary to protect employees from these effects.

The PEL for Methyl bromide is proposed to be lowered from 5 ppm (20 mg/M<sup>3</sup>) to 1 ppm (3.88 mg/M<sup>3</sup>). The proposed limit is based on the observation of hyperplasia of the basal cells, focal thinning of the olfactory epithelium, and occasional cyst like glandular structures in the sub mucosa at 3 ppm in rats. The 1 ppm limit for methyl bromide was adopted by the ACGIH in 1997, and is consistent with the recommendation of the Committee. The proposed limit is supported by the ACGIH document for methyl bromide and is necessary to protect employees from the effects noted.

The PEL for Methyl 2-cyanoacrylate is proposed to be changed from 2 ppm (8 mg/M<sup>3</sup>) to 0.2 ppm (0.908 mg/M<sup>3</sup>) and the current STEL of 4 ppm is proposed to be deleted. This change is based on observations of nasal irritation in a controlled exposure study. This change was adopted by ACGIH in 1998 and is consistent with the recommendation of the Committee. The proposed limit is supported by the ACGIH document for methyl 2-cyanoacrylate and is necessary to protect employees from this effect.

The PEL for Methyl methacrylate is proposed to be changed from 100 to 50 ppm (410 to 205 mg/M<sup>3</sup>). The change to this level was adopted by ACGIH in the year 2000 based upon observations of pulmonary edema in male rats exposed to 116 ppm over a 3 month period and based upon numerous workplace studies identifying human pulmonary deficits after repeated exposures at concentrations greater than 50 ppm. Changes in olfactory (smell) function have also been associated with workplace exposures to methyl methacrylate. The Committee recommended a change in the PEL to 20 ppm based primarily on the study of Marez (1993) which identified cross-shift pulmonary function declines in workers with an average exposure to methyl methacrylate of approximately 20 ppm. At a meeting of the Committee on March 12, 2004, representatives of the Methacrylate Producers Association (MPA) questioned the accuracy of the exposure measurements and the significance of the health effects identified by Marez. The minutes of the March 12 meeting indicate that the MPA representative said that company annual physical examinations of the employees in the study did not find any chronic or major effects on the workers evaluated by Marez. However, these and other similar medical findings by producer companies for these and other similarly exposed workers were not published in the scientific literature. On March 30, 2004, there was additional discussion between Division staff and representatives of the MPA on the scientific basis for the PEL recommendation of 20 ppm. In light of the questions raised by the Methacrylate Producers Association about the validity of the conclusion of Marez, the Division is proposing to adopt the ACGIH TLV of 50 ppm as a time-weighted average for methyl methacrylate. The ACGIH Short Term Exposure Limit (STEL) of 100 ppm (410 mg/M<sup>3</sup>) is also proposed to be adopted. The proposed changes are necessary to reduce the risk of pulmonary and olfactory effects among workers exposed to methyl methacrylate.

The PEL for Molybdenum, soluble compounds, as Mo of 5 mg/M<sup>3</sup> total dust is proposed to be replaced by a respirable fraction limit of 0.5 mg/M<sup>3</sup> based on alveolar/bronchiolar epithelium metaplasia observed in mice at 10 mg/M<sup>3</sup> by Chan, P.C, et al. The proposed limit of 0.5 mg/M<sup>3</sup> was adopted by the ACGIH in 2001. The proposed limit is different from a lower recommended limit by the Committee. The Committee referred to the Chan study and noted that the clear adverse effects noted in mice at 10 mg/M<sup>3</sup> had not been accounted for in the ACGIH

recommendation. The Committee also noted that the Chan study showed significant levels of lung cancers in male mice at 10 mg/M<sup>3</sup>. During the March 30, 2004, advisory meeting Gary Von Riper noted the molybdenum used in the Chan study had been "micronized" and was much more potent at producing harmful effects than the same material with larger particle size distributions that are normally found in occupational settings. Based on this additional advisory opinion, the 0.5 mg/M<sup>3</sup> level based on the ACGIH documentation is recommended. The proposed change is necessary to prevent adverse pulmonary effects observed in laboratory animals.

The PEL for Propylene oxide is proposed to be changed from 20 ppm (50 mg/M<sup>3</sup>) to 2.0 ppm (4.8 mg/M<sup>3</sup>). The proposed limit is necessary to control harmful upper respiratory effects, and the possibility of nasal cancer that has been observed in several species of laboratory animals. This proposed limit was adopted by the ACGIH in 2001. The ACGIH limit was set based on non-cancer effects observed in laboratory animals. The Advisory Committee considered these effects and relied on a 1994 risk assessment by the United States Environmental Protection Agency (USEPA). This assessment estimated a carcinogenic risk of 1/10000 at 0.03 mg/M<sup>3</sup> for 24 hour-7 day exposure. The Committee estimated that this was equivalent to a 1/1000 risk for an occupational exposure at 0.7 ppm propylene oxide. At the March 30, 2004, advisory meeting, additional scientific and feasibility data was provided that supported the ACGIH TLV level of 2 ppm instead of the Committee's recommended level. The proposed change is necessary to prevent harmful respiratory effects noted above and is supported by the ACGIH document for propylene oxide.

A new PEL for 1,3,5 Triglycidyl-s-triazinetriene is proposed at 0.005 mg/M<sup>3</sup>. This limit is necessary to control reproductive effects seen in laboratory animals and cytotoxic and alkylating capacity seen in human clinical trials for this compound. The proposed limit differs from the 0.05 mg/M<sup>3</sup> TLV adopted by the ACGIH in 1997. The Committee generally agreed with the rationale stated in the documentation for this substance but felt that the limit needed to be lower given the anti-neoplastic properties of this compound and the carcinogenic risk associated with similar chemotherapeutic agents. No further changes to the proposal were recommended during the March 30, 2004, advisory meeting.

A new PEL for Vinylidene fluoride is proposed at 100 ppm (262 mg/M<sup>3</sup>). This limit is necessary to control liver toxicity that has been observed in laboratory animals and is similar to the effect observed with exposure to vinyl chloride and vinylidene chloride. The proposed limit differs from the ACGIH limit of 500 ppm adopted by the ACGIH in 1999. The Committee agreed with the ACGIH that vinylidene fluoride seemed 100 times less potent than vinyl chloride at causing liver toxicity, but recommended a limit of 100 ppm because the current PEL for vinyl chloride is 1 ppm as compared to the ACGIH TLV for vinyl chloride of 5 ppm. No further changes to the proposal were recommended during the March 30, 2004, advisory meeting.

#### DOCUMENTS RELIED UPON

ACGIH Documentation for TLVs printed from "TLVs and Occupational Exposure values-2000", (a compact disk) for the following substances:

Acetone  
Bis (2-Dimethylaminoethyl) Ether (DMAEE)  
Crotonaldehyde  
Epichlorohydrin  
Hexachlorobenzene  
n-Hexane  
Methyl bromide  
Methyl 2-cyanoacrylate  
Methyl Methacrylate  
1,3,5-Triglycidyl-s-triazinetriene  
Vinylidene fluoride

Draft ACGIH document for proposed TLV for Beryllium, 2001

ACGIH document for 2-Butoxyethanol, 2001

ACGIH document for Glutaraldehyde, 2001

ACGIH document for 1-Hexene, 2001

ACGIH document for Molybdenum, 2001

ACGIH document for Propylene oxide, 2001

Federal Register, Volume 48, No. 15, pages 2764-2768, January 21, 1983, Occupational Exposure to Coal Tar Pitch Volatiles; Modification of Interpretation

Nelson, K. W., et al, Sensory response to certain industrial solvent vapors. *Journal of Industrial Hygiene and Toxicology*, 25(7), 282-285 (Sept. 1943)

Kreiss, K., et al, Machining risk of beryllium disease and sensitization with median exposures below 2 ug/m<sup>3</sup>. *American Journal of Industrial Medicine*, 30:16-25 (1996)

Eisenbud, M, et al, Non-occupational berylliosis. *Journal of Industrial Hygiene and Toxicology*, Vol. 31, pp. 282-294, Sept 1949

Carpenter, C. P., et al, The toxicity of butyl cellosolve solvent. *A. M. A. Archives of Industrial Health*, 14:114-131 (April 1956)

Chan P. C., et al, Lung tumor induction by inhalation exposure to molybdenum trioxide in rats and mice. *Toxicological Sciences*, 45:58-65 (1998)

Propylene oxide risk assessment, The United States Environmental Protection Agency Integrated Risk Information System (IRIS) 04/01/1994

Letter from Thomas E. Tremble, Advanced Medical Technology Association, dated November 18, 2004, regarding glutaraldehyde

Letter from Susan D. Ripple, The Dow Chemical Company, dated November 19, 2004, regarding glutaraldehyde

Glutaraldehyde Feasibility Summary, submitted by the California Dental Association, November 2004

These documents are available for review from 8:00 a.m. to 4:30 p.m. at the Standards Board Office located at 2520 Venture Oaks, Suite 350, Sacramento, California.

#### DOCUMENTS INCORPORATED BY REFERENCE

None.

#### REASONABLE ALTERNATIVES THAT WOULD LESSEN ADVERSE IMPACT ON SMALL BUSINESSES

No reasonable alternatives were identified by the Board and no reasonable alternatives identified by the Board or otherwise brought to its attention would lessen the impact on small businesses.

#### SPECIFIC TECHNOLOGY OR EQUIPMENT

This proposal does not mandate the use of specific technologies and equipment.

#### COST ESTIMATES OF PROPOSED ACTION

The subject proposal is a revision of an existing standard which specifies airborne exposure limits for chemical substances. The primary users of these substances are the private industrial and chemical sectors. The exposure limits proposed are consistent with recommendations of the American Conference of Governmental Industrial Hygienists or with scientific findings of which professional health and safety staff and consultants of these entities should be aware. Many of these entities already seek to control employee exposures to these levels in the interest of business continuity and minimization of tort and workers compensation liability. Therefore, the additional expenditures for these entities to comply with the revised standard are estimated to be insignificant to none.

#### Costs or Savings to State Agencies

No significant costs or savings to state agencies is anticipated to result as a consequence of the proposed action.

#### Impact on Housing Costs

The Board has made an initial determination that this proposal will not significantly affect housing costs.

Impact on Businesses

The Board has made an initial determination that this proposal will not result in a significant, statewide adverse economic impact directly affecting businesses, including the ability of California businesses to compete with businesses in other states.

Cost Impact on Private Persons or Businesses

The Board is not aware of any cost impact that a representative private person or business would necessarily incur in reasonable compliance with the proposed action.

Costs or Savings in Federal Funding to the State

The proposal will not result in costs or savings in federal funding to the state.

Costs or Savings to Local Agencies or School Districts Required to be Reimbursed

No costs to local agencies or school districts are required to be reimbursed. See explanation under "Determination of Mandate."

Other Nondiscretionary Costs or Savings Imposed on Local Agencies

This proposal does not impose significant nondiscretionary costs or savings on local agencies.

DETERMINATION OF MANDATE

The Occupational Safety and Health Standards Board has determined that the proposed standard does not impose a local mandate. Therefore, reimbursement by the state is not required pursuant to Part 7 (commencing with Section 17500) of Division 4 of the Government Code because the proposed amendments will not require local agencies or school districts to incur additional costs in complying with the proposal. Furthermore, the standard does not constitute a "new program or higher level of service of an existing program within the meaning of Section 6 of Article XIII B of the California Constitution."

The California Supreme Court has established that a "program" within the meaning of Section 6 of Article XIII B of the California Constitution is one which carries out the governmental function of providing services to the public, or which, to implement a state policy, imposes unique requirements on local governments and does not apply generally to all residents and entities in the state. (County of Los Angeles v. State of California (1987) 43 Cal.3d 46.)



The proposed standard does not require local agencies to carry out the governmental function of providing services to the public. Rather, the standard requires local agencies to take certain steps to ensure the safety and health of their own employees only. Moreover, the proposed standard does not in any way require local agencies to administer the California Occupational Safety and Health program. (See City of Anaheim v. State of California (1987) 189 Cal.App.3d 1478.)

The proposed standard does not impose unique requirements on local governments. All state, local and private employers will be required to comply with the prescribed standards.

#### EFFECT ON SMALL BUSINESS

The Board has determined that the proposed amendments may affect small businesses. However no adverse economic impact is anticipated.

#### ASSESSMENT

The adoption of the proposed amendments to the standard will neither create nor eliminate jobs in the State of California nor result in the elimination of existing businesses or create or expand businesses in the State of California.

#### ALTERNATIVES THAT WOULD AFFECT PRIVATE PERSONS

No reasonable alternatives have been identified by the Board or have otherwise been identified and brought to its attention that would be more effective in carrying out the purpose for which the action is proposed or would be as effective and less burdensome to affected private persons than the proposed action.





Writer's Direct Dial: (213) 978-8100  
Facsimile: (213) 978-8312

**OFFICE OF THE CITY ATTORNEY**  
ROCKARD J. DELGADILLO  
CITY ATTORNEY

APR 17 2005

April 22, 2005

Lucetta Dunn, Director  
California Department of Housing and Community Development  
1800 Third Street  
P.O. Box 952050  
Sacramento, CA 94252-2050

Re: Approval of CPVC (State Clearinghouse No. 2000091089)

Dear Ms. Dunn:

We are writing with regards to the March 3, 2005 proposal of the Department of Housing and Community Development ("HCD") to approve chlorinated polyvinyl chloride (CPVC) drinking water pipe for statewide use in all residential buildings. (State Clearinghouse No. 2000091089). We urge you to prepare an environmental impact report ("EIR") prior to proceeding with any approval of CPVC for drinking water pipe to analyze the environmental impacts of CPVC, to consider alternative pipe materials, and to consider feasible mitigation measures.

The San Francisco Department of the Environment recently published a detailed study on the environmental impacts of various plastic pipe materials. The study compared different pipe materials in terms of chemical hazards, recyclability and performance, with an emphasis on pollution prevention. The study concluded that CPVC plastic pipe should be avoided because it generates highly toxic chemicals throughout its lifecycle, from manufacture, to use, to disposal. The study noted that many of these toxic chemicals leach into drinking water, or escape into the air. The study also concluded that CPVC is very difficult to recycle, and therefore, adds to burdens on landfills. CPVC and PVC were the only pipe materials to receive the rating "avoid" in the study.

Lucetta Dunn, Director  
California Department of Housing and Community Development  
April 22, 2005  
Page 2

HCD's proposal would require all cities and local jurisdictions to approve the use of CPVC in any home or other residential building in the state. The City would thus have no authority to review CPVC on a case-by-case basis, or to deny approval based on environmental or public health risks. We believe that before HCD takes such a major step, the agency should at least thoroughly study CPVC in an EIR, particularly in light of the substantial evidence of environmental impacts related to CPVC set forth in the San Francisco Department of the Environment study. An addendum to a 2000 Mitigated Negative Declaration for a much narrower CPVC approval, (allowing CPVC only in limited areas of the state with water or soil so corrosive that it would corrode metallic pipe), is simply not an adequate substitute for a full EIR.

The City relies on HCD and other state agencies to thoroughly review potentially hazardous building materials prior to approval. In fact, the California Court of Appeal recently held that CEQA review was required prior to the approval of another plastic pipe material (PEX). (*Plastic Pipe and Fittings Assoc. v. Calif. Building Standards Comm.* (2004) 124 Cal. App. 4th 1390). This City filed an amicus brief in that case supporting full environmental review. We believe it is equally important to conduct thorough environmental review through an EIR prior to the approval of CPVC for residential drinking water.

Thank you for considering our comments.

Sincerely,



TERREE BOWERS  
Chief Deputy

RJD:JLB:gz/mrc:(#111769 ssche-03)  
cc: Dave Walls, Manager, State Housing Law Program



NATURAL RESOURCES DEFENSE COUNCIL

April 13, 2005

Lucetta Dunn, Director  
CA Department of Housing and Community Development  
1800 Third Street  
P.O. Box 952050  
Sacramento, CA 94252-2050

APR 15 2005

**RE: Approval of CPVC (State Clearinghouse No. 2000091089) - Oppose**

Dear Ms. Dunn:

On behalf of NRDC (Natural Resources Defense Council), which has over one million members and activists, more than 250,000 of whom are Californians, I am writing to express serious concerns about the health and environmental impacts of the proposal of the Department of Housing and Community Development ("HCD") to approve chlorinated polyvinyl chloride (CPVC) drinking water pipe for statewide use in residential buildings. (State Clearinghouse No. 2000091089).

HCD's proposal would require all cities and local jurisdictions in California to allow the use of CPVC in any residential building. Before HCD makes a decision with such major environmental and health implications, the agency should fully study CPVC in an environmental impact report (EIR). An addendum to a 2000 Mitigated Negative Declaration for a much narrower CPVC approval, (allowing CPVC only in limited areas of the state with water or soil so corrosive that it would corrode metallic pipe), is simply not an adequate substitute for a full EIR.

A study recently released by the San Francisco Department of the Environment assessed the environmental impacts of various plastic pipe materials. The study compared the chemical hazards, performance, and recyclability of various materials. The study concluded that CPVC pipe should be avoided for use in water systems because it generates highly toxic chemicals throughout its lifecycle, and because these toxic chemicals can leach into drinking water. The study also concluded that CPVC is very difficult to recycle and adds to burdens on landfills.

I urge you to prepare an environmental impact report ("EIR") prior to proceeding with any approval of CPVC for drinking water pipe to analyze the environmental impacts of CPVC, to consider alternative pipe materials, and to consider feasible mitigation measures.

Sincerely,

Gina M. Solomon, M.D., M.P.H.  
Senior Scientist

FILE

## CALIFORNIA LEGISLATURE

STATE CAPITOL  
SACRAMENTO, CALIFORNIA  
95814

April 12, 2005

Lucetta Dunn, Director  
California Department of Housing and Community Development  
1800 Third Street  
P.O. Box 952050  
Sacramento, CA 94252-2050

RE: Statewide Approval of CPVC

Dear Ms. Dunn:

As Chairs of the policy committees covering the areas of Environmental Quality, Housing and Community Development, Environmental Safety and Toxic Materials, Natural Resources, and Air and Water Quality, we are responsible for ensuring that state law adequately safeguards the health and safety of California citizens and also protects the California environment. We are concerned that the process being used for the recent proposal of the Department of Housing and Community Development (Department) to approve chlorinated polyvinyl chloride (CPVC) drinking water pipe for statewide use may threaten the people and environment of California.

The Department's recently circulated Draft Addendum to the Final Mitigated Negative Declaration Amending Section 604.1 of the California Plumbing Code would approve CPVC in any home or other residential building in the state by removing the existing regulatory restrictions on the use of CPVC potable water piping. The current regulatory limitations on CPVC balance the need for an alternative to metallic piping where such pipe would fail due to corrosive soil and/or water conditions that occur to a very limited extent in certain areas of California.

The amendments being proposed to the California Plumbing Code by the Department would allow the unrestricted statewide use of CPVC drinking water pipe and represent a significant change to current regulatory law. In the past, the Department itself initiated but never completed an environmental impact report (EIR) on the statewide use of CPVC. We are

Lucetta Dunn, Director  
California Department of Housing  
and Community Development  
Page 2

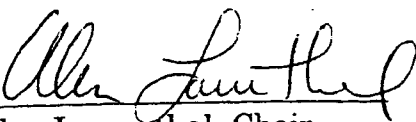
concerned that the Department's proposed "Addendum" attempts to effect a statewide approval of CPVC without disclosing to the public the scope of the proposed approval and without completing the public health and safety and environmental reviews that the Department previously determined necessary. We do not believe that approving CPVC by way of an Addendum is an adequate substitute for comprehensive environmental review required by the California Environmental Quality Act (CEQA).

We believe that the proposed approval of CPVC without resolving the numerous concerns associated with the drinking water pipe is not only bad public policy, but is inconsistent with the requirements of CEQA. The Legislature has never taken action to exempt the approval of potentially hazardous new building materials from CEQA review. The application of CEQA in this context was recently explained by the Court of Appeal in *Plastic Pipe and Fittings Assoc. v. California Building Standards* (2004) 124 Cal.App.4<sup>th</sup> 1309.

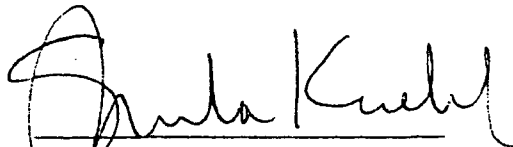
In 2001, the state regulatory agencies responsible for approving new building standards and materials unanimously decided that conducting a CEQA review before approving potentially hazardous new potable water piping was necessary to protect the health and safety of all Californians. The Court of Appeal in *Plastic Pipe and Fittings Assoc. v. California Building Standards* determined that the state agencies' prudent decision was legally correct after challenge by the plastic pipe manufacturers.

Given the history of controversy regarding the approval of CPVC potable water piping, and given the numerous health, safety, and environmental concerns associated with the pipe, we urge you to withdraw the draft Addendum to the Mitigated Declaration and prepare an EIR. This action would enable the state regulatory agencies to take necessary steps to ensure protection of all Californians and would avoid the cost and delay that would result from further litigation.

Sincerely,

  
Alan Lowenthal, Chair  
Senate Committee on Environmental Quality

Lucetta Dunn, Director  
California Department of Housing  
and Community Development  
Page 3



Sheila Kuehl, Chair  
Senate Committee on Natural Resources and Water



Gene Mullin, Chair  
Assembly Committee on Housing and Community Development



Fran Pavley, Chair  
Assembly Select Committee on Air and Water Quality



Ira Ruskin, Chair  
Assembly Committee on Environmental Safety and Toxic Materials



Loni Hancock, Chair  
Assembly Committee on Natural Resources



STATE OF CALIFORNIA - BUSINESS, TRANSPORTATION AND HOUSING AGENCY  
DEPARTMENT OF HOUSING AND COMMUNITY DEVELOPMENT  
OFFICE OF THE DIRECTOR

1800 Third Street, Room 450  
Sacramento, CA 95814  
(916) 445-4775  
Fax (916) 324-5107  
[www.hcd.ca.gov](http://www.hcd.ca.gov)

ARNOLD SCHWARZENEGGER, Governor



April 20, 2005

The Honorable Alan Lowenthal, Chair  
California State Senate  
Senate Committee on Environmental Quality  
State Capitol, Room 3048  
Sacramento, CA 95814

Dear Senator Lowenthal:

Thank you for your letter of April 12, 2005, in which you expressed concerns about the process to consider the statewide use of Chlorinated Polyvinyl Chloride (CPVC) pipe in residential structures. Please be assured that the Department of Housing and Community Development (Department) is fully committed to compliance with both the spirit and letter of the California Environmental Quality Act (CEQA). In fact, consistent with this commitment, the Department is currently conducting a public comment period over and above the usual requirements called for in the CEQA guidelines. This comment period ends on April 25, 2005.

Please allow me to provide some background history of CPVC and the Department's compliance with CEQA.

The regulations now in effect authorize the use of CPVC where a local building official determines that there is, or will be, a premature failure of metallic pipe. These current regulations resulted from the Department's compliance with the California Superior Court's order in the 1997 case of *Richard Cuffe v. California Building Standards Commission*. In that case, the court prohibited the use of CPVC without compliance with CEQA--a process that commences with an initial study and results in the preparation of either an environmental impact report (EIR) or a negative declaration that an EIR is not necessary. Immediately after that case, the Department voluntarily elected to perform a full EIR. That EIR was completed and concluded that no significant adverse effects would result from the approval of CPVC. However, once again, the EIR was challenged through litigation by parties who have consistently opposed the use of any non-metal alternative plumbing material. This case was settled through the preparation of an initial study, as ordered by the court and required by CEQA, and the completion of a mitigated negative declaration, also consistent with the court's order and also in full compliance with CEQA. The mitigation measures enumerated in the negative declaration were, and are, those measures which ensure the health and safety of the installers and consumers from all identified and known potential hazards.

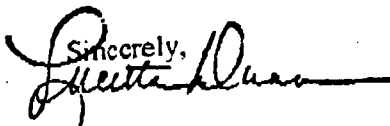
The Honorable Alan Lowenthal  
Page 2

The current proposal would, as you have noted, have the potential effect of expanding the use of CPVC on a statewide basis by removing the requirement for a local finding of premature pipe failures, but none of the mitigation measures are being deleted. All of the existing mitigation measures required, which ensure the safety of both the installers and the consumers, remain fully in place. Therefore, all health, safety, and environmental concerns have been fully mitigated and will continue to be mitigated. There is no proposal to reduce or eliminate any mitigation measure.

An addendum to an existing CEQA document—in this case, the mitigated negative declaration—is permitted by the CEQA guidelines and is fully consistent with the requirements of CEQA. The process being followed by the Department not only meets all CEQA requirements, but exceeds the guidelines by providing a comment period of the Department's 70-page draft analysis, a process not called for by CEQA or the implementing guidelines. The Department has specifically invited those who contend that there are issues that have not been considered to provide that information for the Department's consideration. To ensure that the public is fully informed, the Department has posted the draft addendum on its web site and directly mailed complete copies to those parties who have traditionally been interested in the issue of alternative plumbing materials, including the known opponents. To argue that the public has not been adequately informed, or has not been provided an opportunity to participate as envisioned by CEQA, is inconsistent with the facts.

Frankly, considering the 30-year history of plastic pipe in California, there can be no doubt that any process followed will be challenged as not being in good faith or consistent with CEQA. However, plastic pipe is, and continues to be, a cost efficient product currently available to consumers in all 49 other states, but denied to Californians. In the absence of health or safety concerns that are not already mitigated, it is simply unfair to California consumers to deny an alternative plumbing material regularly used virtually everywhere else without documented adverse health, safety or environmental effects. Too long has plastic pipe been a political issue, rather than a building standards issue. The courts, as you noted, have ruled that CEQA compliance is a pre-requisite to the approval of certain building standards and the Department is complying and will comply with this legal interpretation. Consistent with these court rulings, we strongly assert that the CEQA process should be followed both by the Department and by those who urge compliance with CEQA. Consistent with the court's rulings, those who have concerns about the use of CPVC should respond within the CEQA process.

I am available to meet with you to discuss any continuing concerns and look forward to working with you to dispel the misinformation you may have received. If you have any questions, please call me at (916) 445-4775.

Sincerely,  


Lucetta Dunn  
Director

The Honorable Alan Lowenthal  
Page 3

cc: Sunne Wright McPeak, Secretary  
Business, Transportation and Housing

The Honorable Sheila Kuehl, Chair  
Senate Committee on Natural Resources and Water

The Honorable Gene Mullin, Chair  
Assembly Committee on Housing and Community Development

The Honorable Fran Pavley, Chair  
Assembly Select Committee on Air and Water Quality

The Honorable Ira Ruskin, Chair  
Assembly Committee on Environmental Safety and Toxic Materials

The Honorable Loni Hancock, Chair  
Assembly Committee on Natural Resources

Richard Costigan, Legislative Secretary  
Governor's Office

April 25, 2005

Lucetta Dunn  
Director, California Department of Housing and Community Development  
1800 Third Street  
P.O. Box 952050  
Sacramento, CA 94252-2050

**RE: Approval of CPVC (State Clearinghouse No. 2000091089) - Oppose**

Dear Ms. Dunn:

I am writing to urge the Department of Housing and Community Development to prepare an environmental impact report ("EIR") prior to proceeding with any approval of CPVC for drinking water pipe, in order to analyze the environmental impacts of CPVC, to consider alternative pipe materials, and to consider feasible mitigation measures.

The Healthy Building Network has extensive experience in analyzing the environmental and human health impacts of chlorinated plastics and their alternatives. Recently we assisted the City of San Francisco Department of Environment with an analysis of various plastic pipe materials. That study compared the chemical hazards, performance, and recyclability of various materials, concluding that PVC pipe, including CPVC, should be avoided because of the generation throughout its lifecycle of highly toxic chemicals that have been prioritized by a number of national and international governments for elimination.

Based upon our experience, we have grave concerns about the environmental and health impacts of HCD's proposal to require all cities and local jurisdictions in California to allow the use of CPVC in any residential building. Before HCD makes a decision with such major environmental and health implications, the agency should fully study CPVC in an environmental impact report (EIR). An addendum to a 2000 Mitigated Negative Declaration for a much narrower CPVC approval, (allowing CPVC only in limited areas of the state with water or soil so corrosive that it would corrode metallic pipe), is not an adequate substitute for a full EIR.

Therefore, I urge you to prepare an environmental impact report ("EIR") prior to proceeding with any approval of CPVC for drinking water pipe to analyze the environmental impacts of CPVC, to consider alternative pipe materials, and to consider feasible mitigation measures.

Sincerely,



Tom Lent - Technical Policy Director

## Jeffrey Slaton

---

**From:** Robert Herman [rherman@hcarchitecture.com]  
**Sent:** Sunday, March 06, 2005 9:43 PM  
**To:** Dave Walls  
**Cc:** Helfand Judith  
**Subject:** CPVC Regulations Proposed Change

Dear Mr. Walls:

I urge you to view the documentary film entitled "Blue Vinyl" before the State of California perpetuates dangerous health conditions associated with the production and disposal of PVC. Producer and Director of Blue Vinyl is Judith Helfand. Her email is: jhp@igc.org. The film was featured on HBO for a long period of time.

Yes, PVC in its inert state, after factory production, appears not to be harmful, much as was the case with asbestos. Production of asbestos killed many factory workers, as did its installation and disposal across the USA. The same situation applies to production and fabrication of PVC, as well as its disposal when it includes chemically breaking down the material, especially by burning.

PVC industry lobbyists have done a good job squashing the truth about PVC's dangers, just as the asbestos and tobacco lobbies, for far too long.

Unless the production of PVC can be shown by unbiased testing to safeguard production workers, and the disposal of PVC can be controlled with prevention of burning and other chemical interactions, the additional use of PVC is unethical.

If PVC remains as dangerous as documented just a few years ago in "Blue Vinyl", then the proposed amendment represents another step by anti-regulation forces to give free-reign to the open market, placing profits above the community's best interests.

Sincerely,

Robert Herman

cc Judith Helfand  
FAIA

Robert Herman, FAIA

Herman & Coliver: Architecture  
363 Clementina Street  
San Francisco, CA 94103  
T: 415.552.9210  
F: 415.552.9811  
E: rherman@hcarchitecture.com



**PHYSICIANS FOR SOCIAL RESPONSIBILITY • LOS ANGELES**

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April 13, 2005

Lucetta Dunn

Director

California Department of Housing and Community Development

1800 Third Street

P.O. Box 952050

Sacramento, CA 94252-2050

APR 18 2005

RE: CPVC (State Clearinghouse No. 2000091089) - Oppose

Dear Ms. Dunn:

Physicians for Social Responsibility-Los Angeles represents over 5,000 medical professionals and supporters in Southern California. I write on their behalf drawing attention to potential harms arising from using chlorinated polyvinyl chloride (CPVC) for drinking water piping in residential buildings.

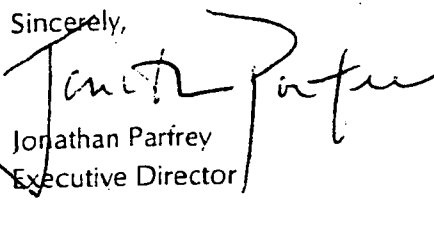
The Department of Housing and Community Development (HCD) proposal requiring municipalities to allow CPVC in residential buildings portends tremendous environmental health implications. A Negative Declaration will not suffice. The agency should study CPVC more fully in an environmental impact report, and, in that process, assess health effects from using CPVC over its entire life, from creation to disposal.

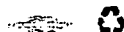
Many of the chemicals used in manufacturing CPVC – dioxins, furans, hexachlorobenzene, and PCBs – are *persistent organic pollutants*, soon to be eliminated by the Stockholm Convention. Because of its chlorine content when CPVC is burned, either in a building fire, or disposed via trash incineration or in a landfill fire, highly toxic dioxins will be released into the environment. CPVC-associated chemicals are known or suspected carcinogens, mutagens, and/or reproductive or developmental toxins.

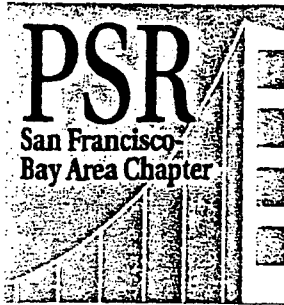
There is further recent compelling evidence that CPVC toxins may leach into drinking water during years of use.

At the very least, HCD should pursue a full EIR on use of CPVC in residential buildings.

Sincerely,

  
Jonathan Parfrey  
Executive Director





Physicians for Social Responsibility

2288 Fulton St., Suite 307

Berkeley, CA 94704-1449

510-845-8395 · Fax: 510-845-8476

info@sfbaypsr.org · www.sfbaypsr.org

APR 18 2005

April 18, 2005

Lucetta Dunn

Director, California Department of Housing and Community Development

1800 Third Street

P.O. Box 952050

Sacramento, CA 94252-2050

**Re: Approval of CPVC (State Clearinghouse No. 2000091089) - Oppose**

Dear Ms. Dunn,

On behalf of the San Francisco Bay Area Chapter of Physicians for Social Responsibility (SF PSR), with approximately 2,000 physician and other health care professional members, I am writing to express our opposition to the proposal of the Department of Housing and Community Development (HCD) to approve chlorinated polyvinyl chloride (CPVC) drinking water pipe for statewide use in residential buildings (State Clearinghouse No. 2000091089). SF PSR is one of the leading organizations in Northern California providing scientifically credible advocacy on environmental health issues. Protecting the public's health is our mission.

It has come to our attention that the HCD is putting forth this proposal, which would require all cities and local jurisdictions in California to allow the use of CPVC in any residential building, without the review of a comprehensive environmental impact report (EIR). A study recently released from the San Francisco Department of the Environment concluded that CPVC pipe should be avoided for use in water systems because it generates highly toxic chemicals that can leach into drinking water, that it is very difficult to recycle and that it adds to the burdens on landfills.

Given the potential public health and environmental implications of this material and its use in water systems, we urge you to consider having a full EIR prepared for your review before making such a decision as that which is outlined in this proposal and to consider alternatives to the CPVC as acceptable pipe material that could be used. Thank you for your attention to this. The public's health and the preservation of our environment require this kind of scrutiny in place when such important, far-reaching decisions are made.

Sincerely,

A handwritten signature in cursive script that reads "Robert M. Gould, M.D.".

Robert M. Gould, M.D.

President

San Francisco Bay Area PSR





**PARTIAL LIST OF UNSUPPORTED STATEMENTS**  
**IN 2005 CPVC DEIR**

“CPVC pipe also is permitted for residential potable water distribution in the other 49 states.” (DEIR at p. 12.)

The proposed Project is the “preferred alternative.” (DEIR at p. 3.)

**Unsupported Statements Regarding Water Quality/Leaching impacts**

“Chemicals released into the water after CPVC installation will be reduced by the inclusion of the LOW-VOC Adhesive requirement.” (DEIR at p. 4.)

*“Table 2 lists the chemicals that may be expected to be released for a short time following CPVC installation and the FWOCA reportable quantity limits.”* [Table 2 lists acetone, cyclohexanone, methyl ethyl ketone and tetrahydrofuran.] (DEIR at p. 52 (emphasis provided).)

During CPVC plumbing installation, the CPVC Adhesives are not reasonably anticipated to be discharged into surface water in the quantities listed. (DEIR at p. 52.)

“Mitigation measures either are already in place or will be implemented to minimize or eliminate potential adverse [water quality] impacts.” (DEIR at p. 58.)

The UPC and CPC “requires flushing of all potable water systems prior to use, regardless of the type of material used.” (DEIR at p.58.)

The requirement to use Low-VOC adhesives “will reduce the amount of cyclohexanone, methyl ethyl ketone, and tetrahydrofuran that will be discharged into the wastewater.” (DEIR at p. 58.)

“The Lead Agency finds that contamination of drinking water by leachates from CPVC and CPVC Adhesives because of CPVC installations pursuant to the proposed project would not have a significant adverse impact on water quality.” “[T]here is no substantial evidence to prove a significant [water quality] impact.” (DEIR at p. 58.)

“There are no health advisories, action levels (Maximum Contaminants Levels and Drinking Water Action Levels), or Public Health Goals established or proposed for CPVC pipe material or Adhesives.” (DEIR at p. 59)

### **Unsupported Statements Regarding Solid Waste Impacts**

“The removal of the Findings Requirement will not result in any new solid waste impacts. While the cumulative effect on solid waste disposal may occur in the future, the effect is not expected to be any greater than the current plastic disposal issues.” (DEIR at p. 5.)

“It is a common construction industry practice for existing pipe to be left in the structure when it is replaced with new pipe.” (DEIR at p. 67.)

“There is no reason to suspect that CPVC solid waste impacts will be any better or worse than other non-bottle plastics.” (DEIR at p. 68.)

“If CPVC pipe is used more extensively in the future in California, it is likely that it too will be recycled.” (DEIR at p. 68.)

“CPVC pipe can be recycled into items such as mobile home skirting, picnic tables, fence posts, and numerous other products. It can also be reused rather than recycled....” (DEIR at p. 68.)

“There is no way of predicting the exact amount or location of this disposal” (DEIR at p. 69.)

“Recycling and reuse of CPVC pipe is both technically feasible and likely given current trends in plastic recycling.” (DEIR at p. 69.)

“The durability and protracted life of CPVC is likely to reduce both the necessity for replacement and any corresponding production of waste.” (DEIR at p. 70.)

## **Unsupported Statements Regarding Air Quality Impacts**

“Operational emissions occur after construction is completed and structures are occupied. Operational values are generally for land use development projects that would result in permanent year-round (365 days) long-term emissions.” (DEIR at p. 42.)

“The use of local air district construction and operational thresholds of significance for VOC emissions are not appropriate standards to evaluate the air impacts for a proposed building code change.” (DEIR at p. 48.)

“Although VOCs will be released during construction which takes place pursuant to the code change, these releases are of short-term duration. Since VOC emissions will not be long-term, local air district significance thresholds for operational values are inappropriate for this project.” (DEIR at p. 42.)

The DEIR’s “Significant and Unavoidable Adverse Impacts” section describes the unavoidable air quality impacts of the project as: “*Short-term* air quality impacts from the proposed project.” (DEIR at p. 73 (emphasis provided.)

“Use of construction values is inappropriate for this Project.” (DEIR at p. 42.)

“The Project would not cause any adverse effect on any state or local air quality plans.” (DEIR at p. 46.)

“The Lead agency has determined that the proposed Project will not violate any air quality standard....” (DEIR at p. 47.)

“The Project would result in fewer emissions than what is currently permitted by local districts with less stringent requirements than the proposed project.” (DEIR at p. 46.)

“Calculations based on reasonable expectations of increased CPVC use and estimations of the amount of cement and primer that would be used due to the proposed plumbing code changes show that the emission of ozone precursors would be small on a county wide and statewide basis.” (DEIR at p. 48.)

“VOC emissions project to occur as a result of the change in the plumbing code are well below background ROG levels emitted by Natural Sources.” (DEIR at p. 47.) “Expected emissions are well below background levels emitted by Natural Sources such as vegetation.” (DEIR at p. 48.)

“The Project is not expected to impact any criteria pollutants other than ozone.” (DEIR at p. 47, 49.) “CPVC installation will not increase particulate matter concentrations.” (DEIR at p. 47, 48.)

“The proposed changes to the plumbing code will not result in any direct or indirect emissions of any criteria pollutants.” (DEIR at p. 48.)

“The increase in volatile organic compound emissions will not occur in substantial concentrations, either within an individual unit or cumulatively.” (DEIR at p. 49.)

### **Unsupported Statements Regarding Worker Health Impacts**

“The removal of the Findings Requirement will not result in any new worker safety impacts.” (DEIR at p. 4.)

“The 2000 MND applied the Cal/OSHA exposure limits then in effect and found that the impacts on worker safety due to worker exposure to CPVC pipe adhesives when installations are performed pursuant to the mitigation measures were less than significant.” (DEIR at p. 63.)

“The Mitigated Negative Declaration analyzed the health impacts of CPVC installation on pipe workers.” (DEIR at p. 65.)

The requirement to use low-VOC CPVC cements and primers will “minimize exposure to chemical contaminants during CPVC installation.” (DEIR at p. 65.)